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The Woody Plants of Iowa in Winter Condition

by

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INTRODUCTION

It was early noticed that woody plants in winter show distinguishing characters by which they may be separated and classified. The lumberman and practical forester have always been able to recognize the various kinds of trees in winter, and the botanist soon began to make descriptions of the twig and bud characters, and to construct keys for their identification.

To one who has never tried, it is remarkable how much can be done towards the recognition of trees and woody plants in general after the fall of the leaves. It has been the experience of the writer that if the species of a genus can be separated readily in flower or leaf, they can be keyed out in winter condition. The only work in this country of a general nature is Trelease's *Winter Botany* (56) which aims to include all our woody plants. Blakeslee and Jarvis have treated the trees of New England in winter (4). In addition to these two works, the winter characters of trees are mentioned in connection with the general descriptions in many manuals, or used to formulate keys. Manuals examined and used in the present work are those of Gates (2), Illick (32), Otis (43), Pool (44), Sargent (53), Rehder (46), Muenscher (42), Schaffner (54), and Shimek (55). A work of more popular interest is Huntington's *Studies of Trees in Winter* (31).

All these keys and manuals, with the exception of Trelease's, are necessarily local or incomplete. Trelease's *Winter Botany,* the last edition published in 1925, is badly in need of expansion and revision. Detailed work upon the woody plants of an area such as Iowa, including species and genus descriptions of the plants in winter, seems to be necessary. Such work can be expanded into or made a part of a more general work including the plants of a larger region. For this reason the present work was undertaken. An article by Foerste in 1892 (16) and a later one by the same author in 1895 (17) called attention to certain characters of the twig and bud which could be used to distinguish trees in winter. Hastings in 1925 (27) published an article along the same lines. Wilson in 1926 (59) called attention to many of these same characters in a rather popular lecture indicating a general interest in the subject.

In addition to the written references listed above the writer has had the very good fortune to have had the personal help and guidance of Dr. B. Shimek of the State University of Iowa throughout this work. His extensive familiarity with woody plants in winter, coupled with a wide knowledge of their distribution in Iowa, has been of great value.

Below are listed some of the structures and characteristics used to identify and distinguish woody plants in winter, with a brief discussion of their value.

WINTER CHARACTERS OF WOODY PLANTS

Habit—Within certain limits the general form and appearance of a plant may serve as a help in recognition. The vase-like appearance of the American elm, the narrow cone-shape of the larch, or the fastigiate habit of the branches of the Lombardy poplar are some examples of valuable habit characters. The plants that are typically vines, shrubs, or trees can, of course, be partly identified by habit alone.

A great deal of caution is needed in using these characters. Differences in habitat, or cultural and varietal differences in the cultivated forms may cause plants of the same species to appear unlike.

Bark—The bark of the trunks and large branches has a definite value, especially in those cases where it is striking and unusual, as in the birch, sycamore, horse-chestnut, and beech. The bark often varies, and as soon as these limits of variability are learned, it becomes an important aid. The bark varies, however, in different individuals or on the same tree at different ages. The characters of the bark are usually hard to describe, and a photograph is the best means of giving the reader a true picture of its real appearance. Robinson, in a popular article, called attention to the value of the bark as an aid in recognizing trees (49).

Twig characters—These include the relative size, color, pubescence, and length of nodes of the twigs. All these characters are rather difficult to describe, and in the case of size the ordinary measurements do not allow for the unusual specimen. Sometimes the twig has corky wings or outgrowths; but these may not always be present. Gregory in a series of three articles (22, 23, 24) called attention to some specific examples of such cork formation.

The lenticels are often of value, especially in those cases where they differ in shape, as in the genus *Prunus*. The color, relative size, and shape of the pith in section, and whether it is spongy or chambered is of great value and should be used when possible.

Leaf scars—These are of great value. The opposite or alternate arrangement of the leaf scars usually forms the main categories of a key. This is rarely obscure, as reported by Boodle for the ash (5).

But the shape and size of the leaf scars, and their position in relation to the bud and to the twig, together with the shape and number of the bundle scars are probably the best single character for identification.

Sometimes abscission scars of branches, or fruit inflorescences are found on the twig, as reported by Clute (7), and these may be of some value.

Buds—The buds give us some valuable characters. Sometimes the buds are partly concealed by the leaf scars or the surface of the twig. This was noticed in 1883 by Hildebrand (28). Sometimes the bud scales are lacking entirely, as was found by Coville to be the case in most of the desert plants he studied (10).

Küster (34) found that the buds he examined grew in size very little during the winter months. But the bud size varies on different plants or even on different parts of the same plant. Within certain limits, however, the size of the bud can be used.

Multiple buds, noticed in 1858 by Damaskinos and Bourgeois (11), in 1890 by Prunet (45), in 1892 by Russell (51), and in 1895 by Foerste (17), are of value but sometimes are lacking from plants normally possessing them.

In a popular article Robinson (48) called attention to the value of buds as a help in identifying trees.

Bud content—This part of the work has been much neglected. Most workers seem not to realize that a simple dissection of the bud will reveal characters that may be of great value in identifying plants. The number, color, and pubescence of the inner bud scales is often a help. Moore found that the full number of leaves was present over winter in most of the buds studied (41). Foster in a morphological study of the horse-chestnut (18) and the hickory (19) found the leaves organized and definite throughout the winter. In the bud dissection carried on in this study very few buds failed to give information about the leaf within. The vernation, type of margin, pubescence, presence or absence of stipules, and the simple or compound condition of the leaf can usually be made out.

The vernation of the leaves may be a definite aid, but little work has been done upon this subject. In 1851 Wydler listed several types of vernation and gave some examples of each type (60). Engelmann in 1877 gave the vernation of some of the species of oaks and stated, "I believe that the characters of vernation will not only help to distinguish allied species or doubtful varieties but will also assist

in unraveling the intricate questions of hybridity" (15). Davenport in 1878 (12) suggested using vernation as a means of distinguishing between the species of *Botrychium* and employed it in a short key to the species.

The first paper that gave information concerning vernation as it occurs throughout the different families of plants was by Diez in 1887 (14). In 1893 Reinecke (47) continued this work in the families Compositae, Campanulaceae, and Lobeliaceae. In the same year Hitchcock, in connection with a description of opening buds, listed the vernation of a number of woody plants (30). In a series of papers published in 1891 (35), in 1895 (36), and in 1897 (37), Sir John Lubbock gave the vernation of a number of plants.

Arnoldi in 1900 described and gave some illustrations of vernation in a number of plants (1). In 1901 Hinze continued this same work through many plant families (29). Since that time, to the writer's knowledge, there has been no general contribution to the information concerning vernation as it occurs in plants. Since many genera that may resemble each other in twig and bud characters often differ strikingly in the vernation of their leaves, information concerning vernation can be a definite aid in identifying plants in winter.

In many cases the flower parts are defined in the bud at the close of the leaf period. Mangin in 1888 (38) found that the flower parts of the cherry were present on August second and by the end of September were well constituted. Wiggans in 1925 (58) noticed that the Bartlett pear began fruit bud formation the first week in July and by October thirtieth the petals were lengthening. Gunderson in 1932 (25) in studying the flower buds of Rhododendron found that the ovaries and ovules were distinct in winter.

In those plants with flowers that appear in the early spring the flower parts are very definite and even the color may sometimes be recognized. In many of the woody plants used in this work the flowers in the bud were far enough developed so that by dissecting a flower bud and a leaf bud the specimen could be run down in an ordinary manual. A study of the inner contents of the buds may be of great value in identifying a woody plant in winter, if a little time is taken to make the necessary dissection, which should be done if possible with the aid of a binocular microscope.

Leaf remnants—In many cases, as among the oaks, the dried leaves habitually remain on the twigs until late in the spring. Often leaf

remnants may be found by searching the plant and these may be a great help in determining a species.

Fruit remnants—Many trees and shrubs hold their fruit over most of the winter. Hamblin (26) and Krebs (33) called attention to some shrubs that possess this habit. The fruit, when present, becomes a definite aid. Schaffner (54) and Shimek (55) include identification keys based on fruit characters.

NATURAL VALUE OF WINTER CHARACTERS

The characters used to identify woody plants in winter are in the main artificial. It can hardly be said that there is any set of winter characters running through an entire family which would serve to place it apart. There are a few genera, such as *Viburnum*, *Cornus*, and *Rhamnus*, whose species exhibit among themselves great diversity in their winter characters. Nevertheless in the vast majority of cases the genus constitutes a fairly definite unit and the species within it possess generic characters of twig or bud in common. Therefore the first division of the key will naturally be a key to the genera.

METHODS

Native or introduced woody plants in the State of Iowa were located and identified during the flower, fruit, and leaf periods. Several manuals were used in this type of work. By far the most valuable one was Rehder's (46). Other general manuals that were consulted were Bailey (3), Gray's Manual, seventh edition (21), Rydberg (52), Britton and Brown (6), and Sargent (53).

Local manuals used were Deam (13), Rosendahl and Butters (50), Pool (44), Gates (20), Otis (43), and Matton and Anderson (39).

A number of keys have been published available for this region. Those used were Trelease (57), Shimek (55), Muenscher (42), Schaffner (54), and Conard (9).

The plants so located and identified were tagged and twigs were collected from them the following winter. From these twigs drawings and descriptions were made. The buds were then carefully dissected and the contents described. Next a detailed description of the species in leaf and fruit was written. From this information genus and species descriptions were made. Then keys to the genera and to the species within the genera were constructed.

Only the deciduous woody plants and evergreen Angiosperms are included in this work. The evergreen Gymnosperms can readily be identified by the use of an ordinary manual or leaf key.

THE USE OF THE KEY

The first part of the work is a key designed to take the user directly to the genus. It is strictly dichotomous in all cases and only one choice is necessary. Because of the diversity or variability of their species, some genera appear in more than one place in the key. Therefore, it is a good plan in all doubtful cases to run through the plant in more than one group.

Since a key must of necessity be brief, and since many of the characters used do not give the user an accurate mental visualization of them, at the end of the manual a series of explanatory notes is given covering definite categories in the key. These categories are followed by a number referring to the note explaining, interpreting, and giving cautions concerning them. These notes in turn refer to figures in the plates which illustrate the characters under consideration. These need be consulted only in case of doubt.

The genera are arranged under families and according to the sequence adopted in Rehder's Manual (46), employed because both cultivated and native species are included in it. When more than one species is found in a genus, a key to the species is added. Because of lack of space the species descriptions are not included here. A star before the species indicates that the plant is not native to Iowa. An interrogation point before the star means that there is question as to whether the species is really native or introduced.

It must be kept in mind that many species, especially the unusual cultivated ones, may not have been located in the present work. New forms are constantly being introduced into the state. These may not appear in the keys. It is hoped, however, that the common species of native and cultivated woody plants, those most apt to be located and worked with, have been included in this work.

KEY TO GENERA

Leaf scars opposite or whorled (Note 1).

2. Stems climbing or twining, vine-like (Note 2).
   3. Climbing by coiled, persistent leaf petioles; stems 6- to 12-ridged, with cavities in cortex under ridges. —*Clematis*, p. 51
   3. Not climbing by coiled petioles; stems either without ridges or only 4-ridged; no cavities in cortex.
      4. Evergreen or almost so; twigs greenish; opposite leaf scars not connected by transverse ridges. —*Evonymus*, p. 78
      4. Deciduous; twigs not greenish; opposite leaf scars connected by a transverse line, sometimes faintly.
         5. Bundle scar 1 and C-shaped; not over 6 bud scales visible —*Campsis*, p. 99
         5. Bundle scars 3; more than 6 bud scales visible. —*Lonicera*, p. 103

2. Stems upright or at most scrambling; trees or shrubs (Note 2).
   6. Evergreen (Note 3).
      7. Twigs 4-lined below the node; rather square in cross-section (Note 4).
         8. Lvs. present as mature structures, oblong to elliptical; opposite leaf scars not connected.
            9. Pith greenish; lvs. entire. —*Buxus*, p. 76
            9. Pith soon brown; lvs. usually serrulate. —*Pachistima*, p. 79
         8. Lvs., if present, as partly developed, linear or lanc. structures; opposite leaf scars connected by transverse ridges. —*Hypericum*, p. 86
      7. No lines on twig or these at most very short; twigs terete (Note 4).
         9a. Lvs. in whorls or crowded near end of twig. —*Kalmia*, p. 91
         9a. Lvs. opposite, not crowded near the end of twig.
            10. Low, almost procumbent; definitely evergreen. —*Daphne*, p. 87
            10. Upright; only partly evergreen. —*Ligustrum*, p. 97
   6. Leaves deciduous or drying on the twig (Note 3).
      11. Spines present (Note 5).
         12. Buds superimposed, widely spreading. —*Forestiera*, p. 96
         12. Buds solitary or collateral, almost or completely appressed.
            13. Twigs covered with peltate, scurfy scales; outer bud scales almost as long as the bud. —*Shepherdia*, p. 88
            13. Twigs without peltate, scurfy scales; outer bud scales short. —*Rhamnus*, p. 82
      11. No spines present (Note 5).
         14. Bundle scars 3 or in 3 groups (Note 6).
            15. Pith excavated or very spongy in the internodes (Note 7).

16. Twigs stellate-pubescent; buds solitary or collateral, never superimposed. —*Deutzia*, p. 56

16. Twigs not stellate-pubescent; buds often superimposed. —*Lonicera*, p. 103

15. Pith solid and continuous (Note 7).
 17. Leaf scars horse-shoe shaped, more than half encircling the bud (Note 8).
  18. Opposite leaf scars connected by a transverse ridge; twigs pubescent, cortex not yellow. —*Calycanthus*, p. 54
  18. Opposite leaf scars not connected; twigs glabrous, cortex yellow. —*Phellodendron*, p. 76
 17. Leaf scars not horse-shoe shaped, not more than half encircling the bud (Note 8).
  19. First bud scale next to the twig, the edges almost meeting in front of lateral bud. —*Cercidiphyllum*, p. 50
  19. First bud scale of lateral bud not as above, or bud concealed.
   20. Opposite leaf scars meeting or connected by a transverse ridge at least near end of twig (Note 9).
    21. Twigs with long. ridges, 2 of which extend down the twig from a point midway between opposite leaf scars.
     22. Buds partly or completely concealed by the leaf scar. —*Philadelphus*, p. 55
     22. Buds not at all concealed. —*Diervilla*, p. 102
    21. Twigs without ridges or with ridges that never extend down from a point between opposite leaf scars.
     23. Buds partly or completely concealed by the leaf scar. —*Philadelphus*, p. 55
     23. Buds not concealed by the leaf scar, though sometimes partly hidden by the base of the petiole.
      24. Pith large, over one-half and usually at least two-thirds the diameter of the twig; very soft wooded (Note 10).
       25. Twigs pubescent. —*Hydrangea* p. 56
       25. Twigs glabrous.
        26. Pith brown; buds often stalked. —*Sambucus*, p. 100
        26. Pith white; buds sessile.
         27. Buds short, conical, often superimposed; lenticels large; bundle scars often more than three. —*Sambucus*, p. 100
         27. Buds oblong to ovoid, not superimposed; lenticels inconspicuous; bundle scars three. —*Hydrangea* p. 56
      24. Pith seldom over one-half the diameter of the twig; definitely woody (Note 10).
       28. Twigs stellate-scurfy pubescent. —*Viburnum*, p. 100

28. Twigs glabrous or pubescent with hairs not stellate.
    29. First two bud scales the length of the bud, often the only ones visible (Note 11).
        30. Some of the buds much enlarged, biscuit-shaped or globose. —*Cornus,* p. 89
        30. Buds not enlarged, biscuit-shaped or globose; if swollen, only at base of bud.
            31. Some of end buds definitely enlarged near base from flower cluster inside, hence rather "flask-shaped" (Note 12).
                32. Buds scurfy but not pubescent, enlarged bud often over 1 cm. long. —*Viburnum,* p. 100
                32. Buds not scurfy, seldom 1 cm. long, at least puberulent. —*Cornus,* p. 89
            31. None of buds enlarged at base from flower cluster (Note 12).
                33. Twigs glabrous.
                    34. Twigs brownish to gray, somewhat long. angled or ridged from below leaf scar. —*Viburnum,* p. 100
                    34. Twigs greenish to reddish, not at all long. angled or ridged. —*Acer,* p. 80
                33. Twigs pubescent to puberulent at least near the ends.
                    35. Terminal bud absent —*Acer,* p. 80
                    35. Terminal bud present or replaced by remains of inflorescence.
                        36. Older twigs conspicuously white streaked. —*Acer,* p. 80
                        36. Older twigs not white streaked.
                            37. Terminal bud often somewhat enlarged at base, fruit if present berry-like in a flat topped or paniculate cyme; pith white or occasionally light tan. —*Cornus,* p. 89
                            37. Terminal bud not enlarged at base; fruit a samara not in flat topped or paniculate cymes; pith orange to brown; very rare in Iowa. —*Acer,* p. 80
    29. First two bud scales shorter than the bud, more than two visible (Note 11).
        38. Leaf scars usually in whorls of three; buds often superimposed. —*Lonicera,* p. 103
        38. Leaf scars rarely whorled; buds not superimposed.
            39. Terminal bud present (Note 13).
                40. Typically trees. —*Acer,* p. 80
                40. Not tree-like —*Viburnum,* p. 100
            39. Terminal bud absent (Note 13).
                41. Twigs puberulent to short villous, becoming shreddy; fruit dry and hispid. —*Kolkwitzia,* p. 102
                41. Twigs glabrous, not shreddy; fruit berry-like and glabrous.
                    42. Twigs long. ridged or angled; buds solitary; fruit red. —*Viburnum,* p. 100

42. Twigs not ridged or angled; buds often collaterally multiple; fruit blackish. —*Rhodotypus*, p. 67

20. Opposite leaf scars separated, not connected by a ridge (Note 9).

43. Only one bud scale visible. —*Salix*, p. 38

43. More than one bud scale visible.

44. Older twigs white striped; two or four bud scales visible. —*Staphylea*, p. 80

44. Older twigs not white striped; usually more than four bud scales visible.

45. Twigs stout; bundle traces more than three; terminal bud usually over 1 cm. long. —*Aesculus*, p. 81

45. Twigs moderate; bundle traces one or three; terminal bud usually small or replaced by a spine. —*Rhamnus*, p. 82

14. Bundle scars not three or in groups of three (Note 6).

46. Bundle scars forming vertically oval ring· trees, with whorled leaf scars. —*Catalpa*, p. 99

46. Bundle scars not forming a ring; leaf scars opposite, or if whorled, never tree-like.

47. Bundle scars four to seven, not confluent; twigs moderate to large (Note 6).

48. Tree; terminal bud large, usually over 1 cm. long. —*Aesculus*, p. 81

48. Typically shrubs; terminal bud small or absent.

49. Older twigs with white streaks; pith moderate in size, the twig definitely woody. —*Staphylea*, p. 80

49. Older twigs without white streaks; pith very large, the twigs soft wooded. —*Sambucus*, p. 100

47. Bundle scars one, or many confluent; twigs small to moderate (Note 6).

50. Opposite leaf scars connected by a transverse ridge (Note 9).

51. Very soft wooded sub-shrubs (Note 14).

52. Twigs square in section; leaf scars U to crescent-shaped with bundle scars in a transverse line. —*Vitex*, p. 97

52. Twigs terete, though often angled or ridged; leaf scars half round to triangular, bundle scars not in a transverse line. —*Buddleia*, p. 97

51. Definitely woody (Note 14).

53. Twigs lined, angled, or ridged. —*Hypericum*, p. 86

53. Twigs not at all angled or ridged.

54. Leaf scars raised, forming a shelf on which the bud sits, bundle scars not U or C-shaped; lenticels not conspicuous. —*Symphoricarpus*, p. 101

54. Leaf scars not forming a definite shelf; bundle scars U or C-shaped; the open side up; lenticels rather conspicuous.

55. Buds very small, appearing partly concealed, usually located some distance above the leaf scar; leaf scars often whorled; fruit remains a globose ball. —*Cephalanthus*, p. 99
55. Buds distinct, located right above the leaf scar; leaf scars never whorled; fruit remains pod-like. —*Campsis*, p. 99

50. Opposite leaf scars not connected by transverse ridges (Note 9).
56. Pith excavated or chambered. —*Forsythia*, p. 94
56. Pith continuous.
57. Twigs with long. corky wings. —*Evonymus*, p. 78
57. Twigs not corky winged though often ridged.
58. Twigs covered with white or brown peltate, scurfy scales. —*Shepherdia*, p. 88
58. Twigs without such scales.
59. Lateral bud with two bud scales visible, bud small, seldom over 1.5 mm. long. —*Kalmia*, p. 91
59. More than two bud scales visible on the larger lateral buds.
60. Buds superimposed (Note 15).
61. Buds at a node separate, not crowded. —*Forestiera*, p. 96
61. Buds crowded at a node, not separate.
62. Bundle scars U-shaped; lenticels very conspicuous; lateral buds seldom 2 mm. long. —*Chionanthus*, p. 96
62. Bundle scars round or oval; lenticels not conspicuous; lateral buds larger. —*Ligustrum*, p. 97
60. Buds not superimposed (Note 15).
63. Twigs green or rosy red; fruit four-lobed. —*Evonymus*, p. 78
63. Twigs brown, olive, or gray; fruit not four-lobed.
64. Buds with tips curved in toward the twig; bundle scars often three; twig often spine-tipped. —*Rhamnus*, p. 82
64. Bud tips not curving in toward the twig; bundle scars always one, or many confluent; twigs never spine tipped.
65. Bundle traces short and little transversly elongated; twigs slender; lenticles inconspicuous. —*Ligustrum*, p. 97
65. Bundle traces as a transverse line C, U or bow-shaped; twigs usually moderate to stout, typically over 2.5 mm. in diameter.

66. Bundle trace U- or C-shaped; lateral buds small, seldom over 2 mm. long. —*Chionanthus*, p. 96

66. Bundle trace bow-shaped; lateral buds usually over two mm. long. —*Syringa*, p. 95

1. Leaf scars alternate (Note 1).

67. Climbing or twining, vine-like (Note 2).

68. Stem with scattered vascular bundles, greenish, often with long. shiny-black prickles. —*Smilax*, p. 37

68. Stem with bundles in a ring or circle.

69. Lvs. definitely evergreen. —*Arctostaphylos*, p. 92

69. Lvs. deciduous or drying on the twig.

70. Spines present at many nodes. —*Lycium*, p. 98

70. No spines present, prickles present or absent.

71. Climbing by tendrils or tendril discs (Note 16).

72. Pith brown, with a solid partition at each node; bark of twig becoming shredded. —*Vitis*, p. 83

72. Pith greenish or white; no solid partitions at the nodes; bark not shreddy.

73. Tendrils twining without disc-like adhesive tips; pith often with partitions extending in from the outer wall. —*Ampelopsis*, p. 84

73. Tendrils usually ending in disc-like adhesive tips; no partitions in pith. —*Parthenocissus*, p. 84

71. No tendrils or tendril discs (Note 16).

74. Leaf scar with a prominent knob-like projection at the lower side; fruit a pod. —*Wistcria* p. 73

74. Leaf scars without such a projection; fruit not a pod.

75. Climbing by aerial roots. —*Rhus*, p. 77

75. No aerial roots.

76. Leaf scars narrowly linear or U-shaped, bundle traces three.

77. Buds almost concealed in a downy hairy pad, almost surrounded by the leaf scar; no prickles. —*Aristolochia*, p. 50

77. Bud not at all concealed, not almost surrounded by the leaf scar. —*Rosa*, p. 68

76. Leaf scars not narrowly linear or U-shaped, bundle scars one or about seven, often indistinct, but not three.

78. Leaf scars large, almost as broad as the twig; bundle scars more than 1; twigs fluted. —*Menispermum*, p. 53

78. Leaf scars moderate to small, bundle scar one or indistinct; twigs sometimes angled but not fluted.
79. Bud scales distinct, keeled, and mucronate at apex; pith not spongy. —*Celastrus*, p. 79
79. Bud scales rather indistinct, obtuse, and not keeled; pith often spongy.
80. Buds pubescent; twigs never spiny. —*Solanum*, p. 98
80. Buds glabrescent; twigs often spiny. —*Lycium*, p. 98

67. Stems upright, trees or shrubs (Note 2).
81. Lvs. evergreen (Note 3).
82. Lvs. compound (Note 28).
83. Lfts. three, entire —*Cytisus*, p. 73
83. Lfts. more than three, spiny toothed. —*Mahonia*, p. 52
82. Lvs. simple (Note 28).
84. Lvs. with margins crenate-serrate to spiny toothed. —*Ilex*, p. 78
84. Lvs. with entire margins.
85. Twigs with two wide wings; hardly woody. —*Genista*, p. 72
85. Twigs terete or at most angled or ridged.
86. Twigs with scale-like flattened hairs. —*Rhododendron*, p 91
86. Twigs without such hairs.
87. Prostrate, trailing plants, branches rooting. —*Arctostaphylos*, p. 92
87. Upright trees or shrubs, or if decumbent, branches not rooting.
88. Stipular scars as a ring encircling the entire twig; often tree-like. —*Magnolia*, p. 53
88. No stipular scars; never tree-like.
89. Lvs. small, less than 2 cm. long; rather procumbent.
90. Lvs. pubescent beneath; leaf scar definitely raised. —*Cytisus*, p. 73
90. Lvs. glabrescent beneath; leaf scar little raised. —*Daphne*, p. 87
89. Lvs. larger.
91. Terminal bud of some twigs much enlarged, often with more than fourteen keeled and attenuated bud scales visible. —*Rhododendron*, p. 91
91. Terminal bud not greatly enlarged, with less than fourteen bud scales visible, these not keeled nor attenuated. —*Kalmia*, p. 91
81. Lvs. deciduous or drying on the twig (Note 3).
92. Spines or prickles present (Note 5).
93. Remains of leaf rachis present as a spine (Note 17).

94. Inner bark and usually the wood and pith lemon yellow. —*Berberis*, p. 52
94. Bark, pith and wood not yellow. —*Caragana*, p. 74
93. Remains of leaf rachis not spiny, usually absent (Note 17).
95. Some of the spines, prickles, or bristles scattered on the internodes.
96. Twigs stout, usually over one cm. in diameter; bundle scars more than three (Note 21).
97. Leaf scars encircling the twig about one-half; pith seldom over one-half total diameter of twig. —*Acanthopanax*, p. 88
97. Leaf scars encircling the twig almost completely; pith large, over one-half the diameter of the twig. —*Aralia*, p. 89
96. Twigs moderate to slender; bundle traces three (Note 21).
98. Spines present at some of the nodes, internodes with bristles or weak prickles.
99. Buds elongate, fusiform, more than six bud scales visible; pith spongy. —*Ribes*, p. 57
99. Buds not elongated, less than six bud scales visible; pith continuous. —*Rosa*, p. 68
98. No spines at nodes.
100. Buds partly concealed by the leaf scar. —*Robinia*, p. 74
100. Buds not at all concealed.
101. Buds hairy-tomentose, especially near the end; leaf petiole usually remaining as a shriveled remnant; leaf scar, if present, oval or flattened oval. —*Rubus*, p. 67
101. Buds glabrous or nearly so; leaf petiole usually deciduous; leaf scar narrow. —*Rosa*, p. 68
95. No spines or prickles on the internodes.
102. Spines or prickles two at a node, stipular (Note 5).
103. Buds wholly or partly concealed by the leaf scar. —*Robinia*, p. 74
103. Buds not concealed under the leaf scar.
104. Twigs long. lined or ridged; bundle scars usually one. —*Caragana*, p. 74
104. Twigs not ridged; bundle scars three.
105. Buds pubescent and indistinctly scaly; leaf scars not narrowly linear or U-shaped. —*Zanthoxylum*, p. 75
105. Buds glabrescent and scaly; leaf scars narrowly linear or U-shaped. —*Rosa*, p. 68
102. Spines or prickles not stipular, usually one or three at a node or as the end of short twigs (Note 5).
106. Pith chambered; stipules covering the woolly mass of buds. —*Prinsepia*, p. 70
106. Pith not chambered; stipules, if present, not covering the bud.
107. Inner bark and usually wood of younger twigs bright lemon yellow when cut. —*Berberis*, p. 52
107. Bark and wood not yellow.

108. Buds and usually the end of twig covered with small brown or silvery, peltate scales. —*Elaeagnus*, p. 88
108. No such scales present.
 109. More than one spine present at a node. —*Ribes*, p. 57
 109. Spines single at a node or as the end of twigs.
  110. Twigs with milky or sticky sap; spine usually lateral to bud. —*Maclura*, p. 49
  110. Twigs without milky or sticky sap; spine above or beneath the bud.
   111. Bundle scars five or more. —*Acanthopanax*, p. 88
   111. Less than five bundle scars present.
    112. Bundle scar one. —*Lycium*, p. 98
    112. Bundle scars three.
     113. Buds partly concealed, superimposed; spines often with two short lateral branches. —*Gleditsia*, p. 71
     113. Buds not at all concealed, solitary or collateral; spines not branched.
      114. Thorns as the ends of short twigs roughened by leaf scars.
       115. Terminal bud absent. —*Prunus*, p. 69
       115. Terminal bud present.
        116. Buds and twigs woolly-pubescent especially near ends. —*Malus*, p. 64
        116. Buds and twigs glabrous or only slightly pubescent. —*Pyrus*, p. 66
      114. Thorns at the nodes smooth, not roughened.
       117. No true terminal bud. —*Chaenomeles*, p. 65
       117. Terminal bud present.
        118. Lateral buds rounded at the tip, reddish; usually trees; spines often over three cm. long. —*Crataegus*, p. 62
        118. Lateral buds pointed at the tip, not reddish; never trees; spines usually shorter. —*Ribes*, p. 57

92. No spines or prickles present (Note 5).
 119. Typically seen as trees (Note 18).

120. Pith five-pointed in cross-section (cut at several places) (Note 7).
 121. Buds partially or wholly concealed by the leaf scar, finally breaking through, commonly leaving it in three plates. —*Robinia*, p. 74
 121. Buds not at all concealed.
  122. Only one bud scale visible. —*Salix*, p. 38
  122. Over one bud scale visible.
   123. No true terminal bud present (Note 13).
    124. Lateral buds with two or three visible scales; leaf scars commonly two-ranked. —*Castanea*, p. 43
    124. Lateral buds with more than three bud scales visible; leaf scars more than two-ranked. —*Prunus*, p. 69
   123. Terminal bud present (Note 13).
    125. Bundle scar as a transverse line, sometimes slightly broken. —*Sassafras*, p. 55
    125. Bundle scars more than one.
     126. Bundle scars more than three and scattered; lateral buds and leaf scars tending to crowd out near the end of the twig. —*Quercus*, p. 44
     126. Bundle scars three or in three groups; lateral buds not crowded near the end of the twig.
      127. Bundle scars forming three rings or U-shaped structures; leaf scars broadly heart-shaped. —*Carya*, p. 40
      127. Bundle scars not forming rings; leaf scars not heart-shaped.
       128. Stipules or stipular scars present and definite.
        129. Shortest bud scale of lateral bud in front; pith usually definitely five-pointed. —*Populus*, p. 37
        129. Shortest bud scale not in front; pith seldom definitely five-pointed. —*Prunus*, p. 69
       128. Stipules or stipular scars not present, or very inconspicuous.
        130. Longer bud scales long-ciliate; buds usually two-ranked; twigs never corky; bark of trunk smooth, native. —*Amelanchier*, p. 64
        130. Bud scales at most short ciliate; buds more than two-ranked; twigs often corky; bark rough; not native. —*Liquidambar*, p. 57

120. Pith round or angled but not five-pointed (Note 7).
 131. Older branches with wart-like twigs on which the leaf scars are crowded (Note 19).

132. Leaf scars of young twigs very numerous; bundle scar one; twigs slender, often bearing cones. —*Larex*, p. 36
132. Leaf scars present on the young twigs only at buds; bundle scars two; twigs moderate to stout, never bearing cones. —*Ginkgo*, p. 36
131. Wart-like twigs absent on older branches, although short lateral twigs may be present (Note 19).
133. Of percurrent growth, the main trunk not branching; trunk with shredding bark; young twigs mostly falling, leaving branch scars. —*Taxodium*, p. 36
133. Open-headed trees; bark of trunk not shredding; twigs not commonly deciduous.
134. Apparently no leaf scar present, the persistent leaf base covering it (Note 17).
135. Twigs long. ridged or angled; leaf-remains not scale-like if present at all; pith central. —*Caragana*, p. 74
135. Twigs not ridged nor angled; leaf-remains a scale; pith not central. —*Tamarix*, p. 87
134. Leaf scar not concealed, definite, although sometimes raised (Note 17).
136. Buds wholly or partly concealed beneath the twig or the leaf scar, or so flattened against the twig as to appear partially concealed (Note 20).
137. Pith colored, not white (Note 7).
138. Pith of older twigs salmon-red; buds superimposed. —*Gymnocladus*, p. 71
138. Pith of older twigs chocolate to yellow-brown; buds not superimposed.
139. Leaf scars horse-shoe shaped, bud end woolly. —*Rhus*, p. 77
139. Leaf scars broad, not horse-shoe shaped; bud-end glabrous. —*Ailanthus*, p. 76
137. Pith of healthy twigs white (Note 7).
140. Twig with gummy or milky sap; bundle scars usually more than three.
141. Twigs yellow to olive green; leaf scars not horse-shoe shaped; bud glabrous. —*Maclura*, p. 49
141. Twigs not yellow or olive green; leaf scars horse-shoe shaped; bud-end woolly. —*Rhus*, p. 77
140. Sap of twig not gummy or milky; bundle scars three.
142. Twigs definitely greenish, usually conspicuously swollen at the node. —*Sophora*, p. 72
142. Twigs not greenish, the nodes not conspicuously swollen.

143. End of bud woolly-hairy; leaf scar definitely horse-shoe shaped; seldom tree-like; fruit not a pod. —*Ptelea*, p. 75

143. End of bud glabrous or indistinctly hairy; leaf scar broad at first, later torn at the top by the developing bud; usually trees; fruit a pod.

144. Twigs shiny; buds superimposed and separate; fruit twisted. —*Gleditsia*, p. 71

144. Twigs not very shiny; buds crowded together under the leaf scar; fruit not twisted. —*Robinia*, p. 74

136. Buds not at all concealed and not flattened as to appear so (Note 20).

145. Pith with diaphragms which often separate chambers, at least near the nodes of the older twigs (Note 7).

146. Stipular scars as a ring surrounding the twig (Note 22).

147. Buds somewhat flattened; leaf scars perpendicularly oval; young lvs. in the bud abruptly bent back. —*Liriodendron*, p. 54

147. Buds not flattened; leaf scars not as above; young lvs. in bud not bent back. —*Magnolia*, p. 53

146. Stipular scars, if present, not as a ring surrounding the twig (Note 22).

148. Bundle trace single, U or C-shaped (Note 6).

149. Bark of older twigs silky-shreddy; buds often superimposed. —*Halesia*, p. 93

149. Bark not silky-shreddy; buds not superimposed.

150. Two bud scales visible. —*Diospyros*, p. 93

150. More than two bud scales visible. —*Eucommia*, p. 58

148. Bundle traces more than one, rarely joined but not forming a U or C-shaped line, sometimes U-shaped, when three are present (Note 6).

151. Bundle scars three U- or circle-shaped structures, the leaf scar three-lobed; pith rather brownish. —*Juglans*, p. 39

151. Bundle scars not three U- or circle-shaped structures, leaf scar not three-lobed; pith whitish.

152. End bud flattened, densely silk-hairy; bundle scars commonly five. —*Asimina*, p. 55

152. End bud lacking, the lateral buds glabrous to puberulent; bundle scars usually three. —*Celtis*, p. 48

145. Pith solid or spongy but not diaphragmed (Note 7).

153. Bundle scars one, or many confluent (Note 6).

154. Bundle scars C-shaped, the open side up; pith typically spongy on older twigs.

155. Only two bud scales visible. —*Diospyros*, p. 93

155. More than two bud scales visible. —*Zelkova*, p. 48

154. Bundle scars not C-shaped; pith continuous except on dried twigs.

156. Buds and usually the twig-ends silvery to brown from small peltate scales. —*Elaeagnus*, p. 88
156. Buds and twigs without such scales.
157. Twigs long. ridged; stipules present as weak prickles. —*Caragana*, p. 74
157. Twigs not long. ridged; no stipular prickles.
158. Twigs and buds greenish shaded with red; strongly aromatic. —*Sassafras*, p. 55
158. Twigs and buds brownish to gray; not aromatic. —*Rhamnus*, p. 82

153. Bundle scars more than one (Note 6).
159. Stipular scars as rings encircling the entire twig (Note 22).
160. Buds conical, without a scar at one side. —*Platanus*, p. 59
160. Buds not conical, a scar present at the side. —*Magnolia*, p. 53
159. Stipular scars if present not as encircling rings (Note 22).
161. Buds naked, no definite bud scales present (Note 23).
162. Leaf scars horse-shoe shaped, almost surrounding the bud.
163. Twigs stout; pith usually yellow-brown. —*Rhus*, p. 77
163. Twigs small to moderate in size; pith white. —*Cladrastis*, p. 72
162. Leaf scars not horse-shoe shaped.
164. Leaf scars two-ranked; flowers or unopened flower cluster present over the winter. —*Hamamelis*, p. 58
164. Leaf scars more than two-ranked; flowers concealed in the bud. —*Rhamnus*, p. 82
161. Buds with definite bud scales (Note 23).
165. Only one bud scale visible. —*Salix*, p. 38
165. More than one bud scale visible.
166. Floral structures present throughout the winter; terminal bud with two lateral stipules simulating bud scales, or, if broken off, leaving scars. —*Hamamelis*, p. 58
166. Floral structures not present except sometimes as partly developed catkins; true bud scales present.
167. Leaf scars two-ranked on the twig in normal, untwisted specimens (Note 24).
168. True terminal bud not present (Note 13).
169. Bud at end of twig obliquely unsymmetrical; the thick bark of the twig showing a ring of triangles in section. —*Tilia*, p. 85
169. Buds symmetrical; no triangular structures in the twig bark.
170. Bundle scars more than three or three groups. —*Morus*, p. 49
170. Bundle scars three or in three groups.

171. Leaf scar fringed at top; flower buds stalked; pith often pink-streaked. —*Cercis*, p. 71
171. Leaf scar not fringed; buds not stalked; pith not pink-streaked.
172. Bud scales two-ranked.
173. Visible bud scales four or less.
174. Buds less than 2 mm. long; bark of trunk not smooth or peeling in papery layers. —*Ulmus*, p. 47
174. Buds over 2 mm. long; bark of trunk smooth or peeling in papery layers on young branches. —*Betula*, p. 40
173. More than four bud scales visible. —*Ulmus*, p. 47
172. Bud scales more than two-ranked.
175. Less than six bud scales visible; bark often peeling in papery layers. —*Betula*, p. 40
175. More than six bud scales visible; bark not peeling.
176. Pith spongy; bark of trunk not smooth nor fluted or scaly; not native. —*Zelkova*, p. 48
176. Pith not spongy; bark of trunk smooth and fluted or scaly.
177. Bark of trunk brownish and scaly; bud scales longitudinally striated under the lens; the bud usually gummy within; partly developed catkins often present. —*Ostrya*, p. 42
177. Bark of trunk smooth, gray, and fluted; bud scales not or very slightly striated; buds not gummy; partly developed catkins never present. —*Carpinus*, p. 42
168. True terminal bud present (Note 13).
178. Some of buds stalked; pith triangular in section. —*Alnus*, p. 41
178. Buds not stalked except by the growth of the twig; pith not triangular in section.
179. More than twelve bud scales visible; leaf scar usually not directly under the bud. —*Fagus*, p. 43
179. Less than twelve bud scales visible; leaf scar directly beneath the bud. —*Amelanchier*, p. 64
167. Leaf scars more than two-ranked on the twig (Note 24).
180. Leaf scars and lateral buds crowding out near the end of the twig, the lateral buds often longer than the terminal (Note 25).
181. Only two to four bud scales visible; lenticels not conspicuous. —*Cornus*, p. 89
181. More than four bud scales visible; lenticels conspicuous. —*Prunus*, p. 69
180. Leaf scars and lateral buds not crowding out near the twig end.
182. Twigs with milky or sticky sap, olive-green to buff-yellow; bundle scars often over three. —*Maclura*, p. 49

182. Twigs without milky or sticky sap, reddish-brown to gray; bundle scars rarely over three.
  183. No true terminal bud present (Note 13).
    184. Accessory buds common. —*Prunus*, p. 69
    184. No accessory buds.
      185. Lenticels conspicuous. —*Prunus*, p. 69
      185. Lenticels not conspicuous.
        186. Pith tan in color; buds reddish-brown, not strongly ciliate. —*Prunus*, p. 69
        186. Pith pale; buds dull brown, definitely ciliate. —*Rhamnus*, p. 82
  183. Terminal bud present (Note 13).
    187. Older twigs usually corky-ridged; pith somewhat spongy; fruit remains a spiny ball. —*Liquidambar*, p. 57
    187. Twigs not corky-ridged; pith continuous; fruit remains not globose-spiny.
      188. Twigs with gummy aromatic sap; heart wood of older twigs yellowish. —*Cotinus*, p. 77
      188. Twigs without gummy or aromatic sap; heart wood not bright yellow.
        189. Bundle scars five. —*Sorbus*, p. 63
        189. Bundle scars three.
          190. Individual bundle scars C- or ring-shaped, the leaf scars heart-shaped. —*Carya*, p. 40
          190. Bundle scars not C- or ring-shaped; leaf scars not heart-shaped.
            191. Some of buds stalked; pith triangular in section. —*Alnus*, p. 41
            191. Buds not stalked except by growth; pith not triangular.
              192. First bud scale as long as the bud, often only two visible.—*Cornus*, p. 89
              192. First bud scale not as long as the bud, more than two visible.
                193. Buds some shade of red, the lateral buds rounded at the tip, the bud scales thick and fleshy. —*Crataegus*, p. 62
                193. Buds varying from brown or gray to dark reddish-brown, at least somewhat pointed, the bud scales usually not thick and fleshy.
                  194. Bud scales definitely gray-pubescent, usually woolly, at least near the end of the bud.

195. Buds often collateral; stipules or their scars present. —*Prunus*, p. 69
195. Buds solitary; no stipular scars.
196. Buds large, usually over 1 cm. long. —*Sorbus*, p. 63
196. Buds smaller. —*Malus*, p. 64
194. Bud scales glabrous or at most ciliate or puberulent.
197. Some of the buds over 7 mm. long.
198. Bud scales with a broad gray marginal band; stipular scars present. —*Prunus*, p. 69
198. Bud scales uniform in color; stipular scars not present.
199. Longer bud scales silky-ciliate; bark of trunk gray and smooth; buds long and narrow; native. —*Amelanchier*, p. 64
199. Longer bud scales slightly if at all ciliate; bark rough; buds ovoid; cult. fruit tree. —*Pyrus*, p. 66
197. None of the buds over 7 mm. long.
200. Older twigs becoming dull gray in color. —*Xanthoceras*, p. 82
200. None of twigs dull gray, except scurf of young twig which rubs off showing reddish-brown beneath.
201. Accessory buds present. —*Prunus*, p. 69
201. No accessory buds present.
202. Leaf scars compressed, semi-oval to half round or triangular; stipules or their scars present. —*Prunus*, p. 69
202. Leaf scars U- to crescent-shaped; no stipules or scar of stipules. —*Malus*, p. 64
119. Typically shrubs (Note 18).
203. Twigs with two broad green wings. —*Genista*, p. 72
203. Twigs terete or at most ridged, not winged.
204. Pith with diaphragms, especially at the nodes (Note 7).
205. Stipular scars as rings encircling the twig. —*Magnolia*, p. 53
205. Stipular scars, if present, not as rings.
206. Older twigs with silky-shreddy bark. —*Halesia*, p. 93
206. Twigs not silky-shreddy.
207. Only two bud scales visible. —*Diospyros*, p. 93
207. More than two bud scales visible.
208. Leaf scars two-ranked; lenticels inconspicuous. —*Symplocos*, p. 93
208. Leaf scars more than two-ranked; lenticels conspicuous or twig warty.
209. Twigs definitely angled or winged. —*Tripterygium*, p. 79
209. Twigs not angled or winged. —*Eucommia*, p. 58
204. Pith without diaphragms (Note 7).

210. Leaf scars not evident, covered by the persistent petiole or leaf base (Note 17).
  211. Twigs angled or ridged; pith central; leaf remains as weak spines. —*Caragana*, p. 74
  211. Twigs not angled or ridged; pith not central; leaf remains scale-like. —*Tamarix*, p. 87
210. Leaf scars definite, though sometimes small or raised (Note 17).
  212. More than three bundle scars present (Note 6).
    213. Stipular scars as a ring encircling the twig. —*Magnolia*, p. 53
    213. Stipular scars, if present, not as a ring.
      214. Leaf scars and lateral buds tending to crowd out near the end of the twig (Note 25).
        215. Buds seldom present, replaced by the scars of fallen branches; or inflorescences; pith terete. —*Hibiscus*, p. 86
        215. Buds present; pith five-pointed in section. —*Quercus*, p. 44
      214. Leaf scars and lateral buds not crowded near twig-end (Note 25).
        216. Stipules persistent; the upper bud commonly developing into a branchlet. —*Colutea*, p. 74
        216. Stipules not persistent; buds not developing until spring.
          217. Leaf scars almost encircling the twig; wood of young twigs bright yellow. —*Zanthorhiza*, p. 51
          217. Leaf scars not almost encircling the twig; wood not bright yellow.
            218. Pith triangular in cross-section; some of buds stalked. —*Alnus*, p. 41
            218. Pith not triangular; buds rarely stalked except by growth.
              219. Twigs with gummy sap or aromatic odor (Note 26).
                220. Bud scales not evident. —*Rhus*, p. 77
                220. Bud scales definite.
                  221. Leaf scars linear or U-shaped; twigs pubescent; low shrub. —*Artemisia*, p. 104
                  221. Leaf scars crescent to triangular; twigs glabrate; often a tall shrub. —*Cotinus*, p. 77
              219. No gummy sap or aromatic odor (Note 26).
                222. Buds large, often over 1 cm. long. —*Paeonia*, p. 50
                222. Buds much smaller.

223. Twigs long. ridged or angled; bud scales definite. —*Physocarpus,* p. 59
223. Twigs not ridged; bud scales not definite.
224. Leaf scars horse-shoe shaped, almost encircling the bud.
225. Twigs stout, with gummy or milky sap. —*Rhus,* p. 77
225. Twigs slender, no gummy or milky sap.
226. Buds short, appearing partly concealed; twigs flexible and rubbery. —*Dirca,* p. 87
226. Buds longer, often over 4 mm. long, not at all concealed; twigs not so flexible. —*Cladrastis,* p. 72
224. Leaf scars not horse-shoe shaped, surrounding the bud less than one-half. —*Rhus,* p. 77
212. Bundle scars three or less (Note 6).
227. Buds wholly or partially concealed beneath the twig surface, or so flattened against it from the end as to appear so (Note 20).
228. Stipules persistent but not spine-like; upper bud usually developing into a small branchlet. —*Colutea,* p. 74
228. Stipules absent or spine-like; buds not commonly developing until spring.
229. Twigs straw colored or gray; bundle scar one. —*Lyceum,* p. 98
229. Twigs brownish to gray; bundle scars three.
230. Weak bristles present on younger twigs. —*Robinia,* p. 74
230. No bristles present.
231. Twigs green, with nodes conspicuously swollen. —*Sophora,* p. 72
231. Twigs not greenish, nodes not conspicuously swollen.
232. Leaf scar broad at first, but usually broken into three plates by the growth of the bud beneath; lenticels not conspicuous. —*Robinia,* p. 74
232. Leaf scars clearly U- or horseshoe-shaped, not broken; lenticels rather conspicuous. —*Ptelea,* p. 75
227. Buds not at all concealed (Note 20).
233. Pith triangular; cones often present. —*Alnus,* p. 41
233. Pith not triangular; cones never present.
234. Incipient or well developed flowers present. —*Hamamelis,* p. 58
234. Flowers concealed in the buds, or as a partly-developed catkin.
235. Low, weak, hardly woody sub-shrubs (Note 14).
236. Twigs glabrous.
237. Twigs greenish in color; not native. —*Kerria,* p. 67
237. Twigs light brown to greenish gray. —*Amorpha,* p. 73
236. Twigs pubescent.

238. Leaf scars narrow-linear to U-shaped; usually more than eight bud scales visible; aromatic odor. —*Artemisia,* p. 104
238. Leaf scar not linear or U-shaped; less than eight bud scales visible; no aromatic odor.
   239. Leaf scars triangular, somewhat three-lobed; twigs usually long. ridged; fruit a small pod. —*Amorpha,* p. 73
   239. Leaf scars not triangular or three-lobed; twigs not ridged; fruit a capsule, usually fallen, leaving a shallow, three-lobed saucer-shaped receptacle. —*Ceanothus,* p. 83

235. Larger, definitely woody plants (Note 14).
240. Bundle scars three (Note 6).
   241. Terminal bud flattened, no evident bud scales. —*Rhamnus,* p. 82
   241. Terminal bud if present not flattened, buds with evident bud scales.
      242. Only one bud scale visible. —*Salix,* p 38
      242. More than one bud scale visible.
         243. Leaf scars and lateral buds tending to crowd out near the end of the twig (Note 25).
            244. Only two to four bud scales visible; lenticels not conspicuous on young growth. —*Cornus,* p. 89
            244. Over four bud scales visible; lenticels conspicuous. —*Prunus,* p. 69
         243. Leaf scars not tending to crowd out near the twig end (Note 25).
            245. End of twig and base of bud with yellow resin dots.
               246. Twigs angled or ridged; leaf scar V-shaped; pith whitish, often spongy. —*Ribes,* p. 57
               246. Twigs not angled; leaf scars triangular; pith greenish, not spongy. —*Myrica,* p. 39
            245. No yellow resin-dots present.
               247. Twigs both greenish and longitudinally angled or ridged (Note 4).
                  248. Stipules remaining; leaf scar oval or kidney-shaped. —*Colutea,* p. 74
                  248. No stipules; leaf scars crescent-shaped. —*Kerria,* p. 67
               247. Twigs not both greenish and longitudinally angled or ridged, rarely either one (Note 4).
                  249. Accessory buds present (Note 15).
                     250. Buds superimposed (Note 15).
                        251. Leaf scars horseshoe-shaped, almost surrounding the bud. —*Cladrastis,* p. 72
                        251. Leaf scars not horseshoe-shaped.

252. Leaf scars two-ranked; pith usually light brown. —*Stephanandra,* p. 59
252. Leaf scars more than two-ranked; pith whitish. —*Amorpha,* p. 73
250. Buds collateral (Note 15).
253. Leaf scars more than two-ranked; commonly three buds at a node, the lateral ones usually broader. —*Prunus,* p. 69
253. Leaf scars two-ranked; sometimes obscurely so; lateral buds usually smaller.
254. Stipular scars present; pith pale, spongy. —*Zelkova,* p. 48
254. Stipular scars not present; pith brown, continuous. —*Sorbaria* p. 61
249. Buds solitary (Note 15).
255. Stipules or stipular scars present, usually very distinct (Note 27).
256. Leaf scars two-ranked (Note 24).
257. Pith whitish and spongy between the nodes; no catkins present; rare. —*Zelkova,* p. 48
257. Pith tan, not spongy; catkins often present; often common.* —*Corylus,* p. 42
256. Leaf scars more than two-ranked (Note 24).
258. Leaf scars narrowly U-shaped, partly surrounding the bud. —*Cydonia,* p. 66
258. Leaf scars not U-shaped.
259. Lateral buds with only two bud scales visible and definite, these lateral and exposing the woolly bud end; fruit a small pome. —*Cotoneaster,* p. 62
259. More than two bud scales visible; fruit not a small pome.
260. Buds woolly near end; twigs greenish to reddish. —*Prunus,* p. 69
260. Buds glabrous or at most ciliate; twigs gray to brownish-red.
261. Lenticels conspicuous; buds glabrous, reddish-brown. —*Prunus,* p. 69
261. Lenticels inconspicuous; buds ciliate, dark-brown. —*Rhamnus,* p. 82
255. No stipules or definite stipular scars present (Note 27).
262. Pith and inner bark orange in color. —*Prunus,* p. 69
262. Pith and inner bark not orange in color.
263. Buds definitely pubescent, often woolly.
264. More than six bud scales visible; pith spongy. —*Ribes,* p. 57
264. Less than six bud scales visible; pith solid. —*Malus,* p. 64
263. Buds glabrous or at most ciliate to sparingly puberulent.
265. Leaf scars linear or narrowly U-or V-shaped (Note 8).

***Betula glandulifera* Butler., a shrubby birch very rare in this state, would fall about here. It differs from *Corylus* by having fewer bud scales visible, of which there are seldom over three.

266. Pith spongy; twigs usually ridged or angled —*Ribes*, p. 57
266. Pith not spongy; twigs not ridged or angled.
267. Buds sitting on shelves formed by the raised leaf scars; leaf scars not extending one-half the way around the twig.
268. First bud scale as long as the bud, often only two visible. —*Cornus*, p. 89
268. First bud scale shorter than the bud, more than two visible.
269. Buds with long acuminate points which usually bend, lateral buds appressed or nearly so.
270. Second shortest bud scale one-half the length of the bud or more. —*Aronia*, p. 63
270. Second shortest bud scale less than one-half the bud length.
271. Bud scales ciliate or glandular-toothed; twigs never spiny.
272. Bud scales silky-ciliate, especially near the end, not glandular-toothed. —*Amelanchier*, p. 64
272. Bud scales glandular-toothed but not silky-ciliate. —*Aronia*, p. 63
271. Bud scales neither silky-ciliate nor glandular-toothed; twigs rarely spiny —*Pyrus*, p. 66
269. Bud tips obtuse or merely acute, straight; lateral buds not appressed.
273. Terminal bud present; more than six bud scales visible on the lateral bud. —*Exochorda*, p. 61
273. Terminal bud lacking; about four bud scales visible on lateral buds. —*Photinia*, p. 64
267. Leaf scars scarcely raised, often extending one-half around the twig. —*Rosa*, p. 68
265. Leaf scars broad to crescent-shaped (Note 8).
274. True terminal bud lacking; low, rather soft-wooded. —*Sorbaria* p. 61
274. Terminal bud present; not soft-wooded.
275. Twigs with a gummy aromatic sap; heart wood on older branches usually yellow. —*Cotinus*, p. 77
275. No gummy aromatic sap; heart wood not yellow.
276. Scales of terminal bud with filiform tips, the lateral buds pointed; pith brownish. —*Xanthoceras*, p. 82
276. Scales of terminal bud rounded at the tip; the lateral buds obtuse; pith whitish. —*Crataegus*, p. 62
240. Bundle scars one or grouped as one aggregate (Note 6).

277. Buds and usually the end of the twig covered with silver or brown scurfy peltate scales. —*Elaeagnus*, p. 88
277. No such scales present.
278. Stipules persistent, if partly broken off then the stipular scar raised (Note 27).
279. Bundle scar an elliptical ring; no evident bud scales; twigs usually stellate-hairy. —*Grewia*, p. 85
279. Bundle scar not in a ring; bud scales evident; twigs not stellate.
280. Leaf scar small, less than two-thirds as long as the width of the bud.
281. Only two bud scales visible, these lateral and exposing the woolly end of the bud. —*Cotoneaster*, p. 62
281. More than two bud scales visible.
282. Twigs definitely ridged from the leaf scar; bark of older twigs close; pith pale. —*Caragana*, p. 74
282. Twigs not or only slightly ridged; bark of older twigs exfoliating; pith brownish. —*Potentilla*, p. 68
280. Leaf scar larger, more than two-thirds the width of the bud.
283. Stipules large, always present; twigs more than two-ridged from each leaf scar.
284. Buds superimposed, the upper commonly developing into a branchlet; usually one bundle scar. —*Colutea*, p. 74
284. Buds solitary or collateral; one bundle scar typical. —*Genista*, p. 72
283. Stipules small or broken off; twigs only two-ridged from each scar.
285. Twigs gray to brown; buds sometimes superimposed. —*Ilex*, p. 78
285. Twigs greenish to gray-green; buds never superimposed. —*Cytisus*, p. 73
278. Stipules absent, stipular scars if present very small and inconspicuous (Note 27).
286. Twigs and buds yellow to tan, scurfy pubescent. —*Clethra*, p. 90
286. Twigs and buds not yellow- to tan-pubescent, although they may be gray-pubescent.
287. Leaf scars mostly whorled or sometimes alt.; lvs. partly evergreen. —*Kalmia*, p. 91
287. Leaf scars always alt., lvs. definitely deciduous.
288. Young twigs definitely greenish in color. —*Cytisus*, p. 73
288. Young twigs not greenish in color.
289. Twigs with two or three ridges or angles from each leaf scar (Note 4).

290. Lenticels large and wart-like; bundle scars C-shaped. —*Tripterygium*, p. 79

290. Lenticels small and inconspicuous; bundle scars not C-shaped.

291. Terminal bud often present; twigs gray to dark-brown; buds commonly superimposed; small stipular scar present. —*Ilex*, p. 78

291. Terminal bud rarely if ever present; twigs straw- to reddish-brown; buds solitary, grouped or collateral; no stipular scar.

292. Twigs reddish-brown to light-brown; pith not spongy. —*Spiraea*, p. 60

292. Twigs light gray to straw-colored; pith spongy. —*Lyceum*, p. 98

289. Twigs either not at all ridged or only one-ridged from each leaf scar (Note 4).

293. Buds long and pointed with usually more than ten bud scales visible. —*Spiraea*, p. 60

293. Buds shorter, ovoid, oblong to globose, less than ten bud scales visible.

294. True terminal bud present (Note 13).

295. Leaf scars definitely raised, usually decurrent; small inconspicuous stipules or their scars present. —*Ilex*, p. 78

295. Leaf scars little raised; no stipules or stipular scars present.

296. Terminal bud with three oblong narrow scales visible, or these falling, leaving scars; wood not fetid. —*Clethra*, p 90

296. Terminal buds with more than three scales visible; fresh-cut wood fetid-smelling. —*Daphne*, p. 87

294. No terminal bud present (Note 13).

297. Bundle scar as a transverse line, sometimes broken into three transverse segments; small stipular scars present (Note 6).

298. Low, scarcely woody, sub-shrubs; fruit remnants usually present as shallow three-lobed saucer-shaped receptacles in a corymbose panicle. —*Ceanothus*, p. 83

298. Definitely woody; fruit remnants seldom present, if so not as above. —*Rhamnus*, p. 82

297. Bundle scar circular, oval or C-shaped, not as a transverse line; no stipular scars (Note 6).

299. Bud-ends and often the twig bearing yellow resin dots. —*Gaylussacia*, p. 92

299. No yellow resin dots present.

300. Bundle scars C-shaped. —*Diospyros*, p. 93

300. Bundle scars small, oval or circular, not C-shaped.

301. Low, dwarf shrubs; twigs reddish-brown; bark of older twigs close. —*Vaccinium*, p. 92

301. Not low or dwarf-like; twigs light-brown to straw-colored; bark of older twigs tending to shred. —*Buddlia*, p. 97

DESCRIPTIONS OF GENERA AND KEY TO SPECIES

Family GINKGOACEAE

GINKGO L. Ginkgo

Habit—Trees with ashy-gray bark, becoming seamed and roughened. **Twigs**—Rather stout, somewhat zigzag, yellowish-brown, bark of older twigs shredding, with many short wart-like twigs on which the leaf scars are crowded. Lenticels not conspicuous. Pith greenish to yellow-tan, irregular in section. **Leaf Scars**—Semi-oval, upper margins usually fringed. Bundle scars two. Stipular scars none. **Buds**—Solitary, chestnut brown, rather conical, about four to five bud scales visible. **Bud Content**—Inner bud scales green-spotted. Lvs. with flattened involute vernation. **Leaf Remnants**—Rather fan-shaped, often two-lobed at apex but with edges entire. **Fruit Remnants**—Falling early, drupe-like, about 2.5 cm. long, present only on the ovulate tree. —**G. biloba* L.

Family PINACEAE

TAXODIUM Rich. Bald Cypress

Habit—Deciduous trees with shredding bark. **Twigs**—Slender, light-brown, glabrous. Lenticels not noticeable. Pith small, brown, sometimes angled and rather spongy. **Leaf Scars**—Usually lacking since many of the young twigs fall, leaving round branch scars, which are alternate and more than two-ranked, containing one bundle scar. Small scales often present, subtending the buds. **Buds**—Small, subglobose, with about four to eight obtuse scales visible, but usually absent or hard to find. **Bud Content**—Too small for detail. **Leaf Remnants**—Appear compound as a foliage spray but actually are simple and narrowly linear. **Fruit Remnants**—Small ellipsoid cone with thickened scales. —**T. distichum* Rich.

LARIX Mill. Larch

Habit—Trees with percurrent trunk which becomes roughened by reddish-brown scales. **Twigs**—Rather slender, older twigs with short wart-like twigs. Lenticels inconspicuous. Pith small, brownish. **Leaf Scars**—Scattered on the young twig or clustered on the short wart-

like twigs, rather triangular to half round. Bundle scar one. Stipular scars none. **Buds**—Small, solitary, brownish with numerous but often indistinct scales. **Bud Content**—Inner scales longitudinally striated. Leaf mass sub-globose. Terminal bud of wart-like shoot with almost hollow area beneath the leaf cluster. **Leaf Remnants**—Flattened linear. **Fruit Remnants**—A persistent, ellipsoid cone with rather thin scales.

1. Cones over 2.5 cm. long, the scales puberulent; twigs yellowish or straw-colored. —**L. decidua* Mill.
1. Cones under 2.5 cm. long, the scales glabrous; twigs typically reddish-brown. —**L. laricina* K. Koch.

Family LILIACEAE

SMILAX L. Green-Brier

Habit—Deciduous, climbing by tendrils. **Twigs**—Rather slender, greenish to gray, often with long black prickles which are slender, not dilated at the base, glabrous. Lenticels not conspicuous. Pith not central but with the vascular strands scattered. **Leaf Scars**—Seldom present, the petiole base remaining. Stipules remaining and tendril-like. Lvs. alternate, appearing two-ranked. **Buds**—Concealed in the petiole base, widely spreading, one bud scale visible. **Bud Content**—Lvs. with broad thin petiole. Stipules at sides of leaves, leaf entire with involute vernation. **Leaf Remnants**—Ovate, cordate, entire, palmately veined. **Fruit Remnants**—Often present as black berries born in umbels. —*S. hispida* Muhlb.

Other woody species have been reported in Iowa such as *S. rotundifolia* L. and *S. pseudo-china* L., but these seem to intergrade with the species here listed or have been doubtfully identified. It seems probable, however, that more than one woody species occurs in the state.

Family SALICACEAE

POPULUS L. Poplar

Habit—Deciduous, mostly trees. **Twigs**—Moderate to stout, terete or angled. Pith usually moderate, greenish-white and becoming tan or brown, five-angled in section. **Leaf Scars**—Alt., more than two-ranked, triangular or three-lobed to crescent-shaped. Bundle scars three. Stipular scars present and often conspicuous. **Buds**—Solitary, flower buds wider, lateral buds usually appressed with three to five scales visible, the shortest one in front. **Bud Content**—Stipules large and rather enclose the lvs. which are simple, vernation involute, rarely slightly so. Flower buds separate, containing catkins, dioecious. **Leaf**

Remnants—Ovate to deltoid or lance-ovate, petiole rather long. **Fruit Remnants**—A two- to four-valved capsule, seeds with silky hairs.

1. Twigs typically three-angled from below each scar.
   2. Twigs greenish to light brown; lenticels very conspicuous on young twigs and very much elongated longitudinally. —**P. generosa* Henry
   2. Twigs greenish to straw colored; lenticels not conspicuous and not over three times longer than broad. —**P. szechuanica* Schneid.
1. Twigs not angled or exceptionally angled on the shoots.
   3. Terminal bud seldom over 10 mm. long, buds not resinous or only slightly so; no definite odor.
      4. Buds glabrous and slightly resinous, narrow, often lanceoloid.
         5. Fastigiate; twigs yellowish to yellowish green; cult. —**P. nigra italica* Dur.
         5. Not fastigiate; twigs gray brown to reddish brown; native, seldom cult. —*P. tremuloides* Michx.
      4. Buds somewhat pubescent, not at all resinous, typically ovoid.
         6. Branches green, fastigiate. —**P. alba pyramidalis* Bge.
         6. Branches not definitely green, spreading.
            7. End of twig coated with a thick cotton-like white felt, easily rubbed away; branches whitish or greenish-white. —**P. alba* L.
            7. End of twig not woolly pubescent; branches greenish. —*P. grandidentata* Michx.
   3. Terminal bud over 10 mm. long, heavily resinous and with a definite odor.
      8. Twigs yellowish; terminal bud usually under 16 mm. long; ill scented; a common species. —*P. balsamifera* L.
      8. Twigs reddish brown to olive brown; terminal bud usually over 16 mm. long, buds fragrant, rare in Iowa. —*P. tacamahaca* Mill.

This genus is fairly easy to recognize, but the nomenclature is not clear, and this adds to the difficulty. *P. balsamifera* as here considered, is the same as the *P. deltoides* of Gray's Manual, seventh edition. This genus often drops its twigs or branches, leaving abscission scars. This habit was noticed and described by Clute (7).

SALIX L. Willow

Habit—Deciduous shrubs or trees. Bark of trunk becoming fissured. **Twigs**—Usually slender, terete. Pith small to moderate, white, round or sometimes angled. **Leaf Scars**—Alt. more than two-ranked, or in one species opposite, narrow U- to V-shaped, often raised. Bundle scars three. Stipular scars present or absent. **Buds**—Appressed, solitary, end bud lacking, only one bud scale visible, bud usually flattened somewhat against the twig, with lateral angles. **Bud Content**—Flower bud always separate and enlarged, flowers in catkins, dioecious. Lvs. simple with straight vernation. **Leaf Remnants**—Simple, pinnately veined, margins toothed, usually long. **Fruit Remnants**—A two-valved capsule; seeds winged.

This is an extremely difficult genus as far as the individual species go in any condition, and a species key is not attempted.

Family MYRICACEAE

MYRICA L. Bayberry; Wax-Myrtle

Habit—Deciduous shrubs. **Twigs**—Moderate, twiggy, gray to deep brown, loose-hairy and resin-dotted. Lenticels inconspicuous. Pith greenish, moderate, somewhat angled. Often aromatic. **Leaf Scars**—Alt., more than two-ranked, rather triangular in shape, little raised. Bundle traces three. No stipular scars. **Buds**—Small, unless enlarged flower buds are present, dark brown to rose colored, often loose-hairy with yellow resin dots at the base of some, about four to seven scales visible. **Bud Content**—Vernation straight, with the leaf ends somewhat pinched together. **Leaf Remnants**—Oblong-lanc., pinnately veined, coarsely serrate near tip, petiole short (2 mm.). **Fruit Remnants**—Drupe 4 to 5 mm. wide, resin dotted.

—**M. caroliniensis* Mill.

Family JUGLANDACEAE

JUGLANS L. Walnut; Butternut

Habit—Deciduous trees. **Twigs**—Stout. Lenticels pale. Pith moderate to large, tan to brown, chambered. **Leaf Scars**—Alt., more than two-ranked, shield shaped to three-lobed, large, raised. Bundle traces three, each usually U-shaped. Stipular scars usually lacking. **Buds**—Moderate to large, often superimposed, the terminal one much larger, with two to four bud scales visible; the outer scales the length of the bud and often with remnants of a compound leaf at the top, scurfy-hairy. **Bud Content**—Scales grade into lvs. which are pinnately compound and hairy, the vernation of the leaflets conduplicate. **Leaf Remnants**—Large, pinnately compound. **Fruit Remnants**—A nut enclosed in an indehiscent husk.

1. Downy pad present above the leaf scar; terminal bud usually elongated; pith light brown to dark brown.
   2. Leaf scar with a notch at top; not native, rarely planted.
      3. Twigs very stout, often over 7 mm. in diameter; nut rugose or smooth, not ridged; pith often light brown. —**J. Sieboldiana* Maxim.
      3. Twigs not so stout, seldom 7 mm. in diameter; nut strongly six to eight ridged; pith brown. —**J. cathayensis* Dode.
   2. Leaf scar without a notch at the tip; native trees, rather common. —*J. cinerea* L.
1. Downy pad absent; terminal bud not elongated very much; pith light brown to tan.

4. Twigs glabrescent; buds puberulent; bark smooth; not native and rare. —**J. regia* L.
4. Twigs pubescent; buds canescent; bark rough; native, rather common. —*J. nigra* L.

CARYA Nutt. Hickory; Pecan

Habit—Deciduous trees. **Twigs**—Moderate to stout. Lenticels pale and conspicuous, long. elongated. Pith moderate to large, five-pointed in section, sometimes obscurely so, pale to brownish. **Leaf Scars**—Alt., more than two-ranked, rather heart-shaped to three-lobed. Bundle scars in three groups, each a circle. Stipular scars none. **Buds**—Sometimes superimposed, rather large, the terminal bud largest. **Bud Content**—Lvs. compound with convolute vernation. Catkins, if present, in terminal bud. **Fruit Remnants**—A nut enclosed in a dehiscent husk.

1. Terminal bud narrow, lanceoloid; bud scales in pairs of equal length, the first pair about as long as the bud and almost covering it.
   2. Buds conspicuously yellow, dotted with conspicuous glands; fruit and nut not elongated, seldom longer than wide. —*C. cordiformis* K. Koch.
   2. Buds yellowish gray, only slightly glandular; fruit and nut elongated. —*C. pecan* Engl. & Graebn.
1. Terminal bud ovoid; bud scales not in pairs, outer scales short or broken off leaving scars.
   3. Bark not shaggy on old trunks; terminal bud broadly ovoid, the outer woody scales falling early. —*C alba* K. Koch.
   3. Bark shaggy on older trunks; terminal bud ovoid, outer scales commonly persistent.
      4. Twigs buff to orange in color, usually somewhat pubescent; native to low grounds. —*C. laciniosa* Loud.
      4. Twigs dark reddish brown, seldom pubescent; native to uplands. —*C. ovata* K. Koch

C. glabra Sweet. has been reported from southern Iowa but if present is very rare.

Family BETULACEAE

BETULA L. Birch

Habit—Deciduous trees. Bark of young trunks and branches white to cinnamon-brown, often peeling in papery layers. **Twigs**—Slender, lenticels pale. Pith greenish white to brown, small to moderate. **Leaf Scars**—Alt., two-ranked, half-oval to triangular-crescent. Bundle scars three, often indistinct. Stipular scars narrow, occasionally conspicuous. **Buds**—Terminal bud absent except on very short shoots, buds solitary, ovoid to lanceoloid, three to four bud scales visible, the first two lateral. **Bud Content**—Leaf between broad scale-like

stipules, hairy on both sides, edges with plicate vernation. **Leaf Remnants**—Simple, doubly serrate, pinnately veined. **Fruit Remnants**—Cone-like stobilus, seeds winged and the staminate catkin usually present on some twig ends.

(Based on bark alone)

1. Bark easily separating into papery layers, generally peeling naturally.
   2. Outer bark layers of young branches whitish. —*B. papyrifera* Marsh. & varieties or **B. pendula* Roth.
   2. Outer bark of young branches not white.
      3. Outer bark layer of young branches reddish-brown. —*B. nigra* L.
      3. Bark layer of young branches dirty yellow to orange. —*B. lutea* Michx.
1. Bark close, not easily separated.
   4. A shrub, never tree-like. —*B. glandulifera* Butler.
   4. Typically a tree. —**B. populifolia* Ait.

(Based on twig and bark characters)

1. A shrub, never tree-like, buds seldom over 3 mm. long. —*B. glandulifera* Butler.
1. Typically trees; buds usually over 3 mm. long.
   2. Bark of young branches gray or whitish.
      3. Buds usually under 6 mm. long; bark close, not easily separating. —**B. populifolia* Ait.
      3. Buds usually over 6 mm. long; bark peeling. —*B. papyrifera* and varieties or **B. pendula* Roth.
   2. Bark reddish brown to cinnamon brown.
      4. Buds unusually under 6 mm. long; both buds and end of the twigs downy hairy. —*B. nigra* L.
      4. Buds usually over 6 mm. long; buds and ends of twigs glabrous or only partly hairy. —*B. lutea* Michx.

Betula is a genus best characterized by its bark and flower remains. Its species are often difficult in winter. *B. lenta* L. has been reported native in Iowa but is doubtfully present. Nursery stock has been sold and planted in Iowa under this name, but the ones examined by the writer were too small for accurate checking.

ALNUS MILL. Alder

Habit—Shrubs or large trees, deciduous. **Twigs**—Slender, terete or rather three sided. Lenticels fairly conspicuous. Pith becoming brown, moderate, definitely triangular in section. **Leaf Scars**—Alt. obscurely two-ranked, half round. Bundle scars three, sometimes U-shaped. Stipular scars narrow. **Buds**—Solitary, rather large and becoming stalked about three bud scales visible, all about the length of the bud. **Bud Content**—Lvs. with stipules, vernation plicate-edged. **Leaf Remnants**—Simple, broad ellipt. to obovate, pinnately veined,

doubly serrate-dentate. **Fruit Remnants**—Often present as cone-like structures, the staminate catkins present over winter.

1. Large tree; twigs and buds glabrous. —**A. glutinosa* Gaertn.
1. Shrub or small tree; twigs and bud ends usually somewhat pubescent. —*A. incana* Moench.

CARPINUS L. Hornbeam; Blue Beech

Habit—Rather small trees, deciduous, bark smooth gray, fluted in long. ridges. **Twigs**—Slender, reddish-brown, sometimes downy pubescent. Lenticels scattered, pale, rather conspicuous. Pith white, moderately large. **Leaf Scars**—Alt. two-ranked, flattened oval. Bundle scars three, often indistinct. Stipular scars not equal. **Buds**—Solitary, the terminal bud absent, reddish-brown, glabrescent except on the edges of the scales. Six to ten bud scales visible in more than two ranks. **Bud Content**—Stipules present with a rather hairy leaf between, vernation plicate edged and somewhat conduplicate. **Leaf Remnants**—Simple, oblong, pinnately veined, doubly serrate. **Fruit Remnants**—A ribbed nutlet with a three lobed bractlet, the catkins all enclosed in the bud. —*C caroliniana* Walt.

This genus resembles *Ostrya* very closely in twig characters, but differs from it most strikingly in the bark.

OSTRYA Scop. Hop-Hornbeam

Habit—Deciduous trees, bark brownish, in small scales. **Twigs**—Slender, reddish-brown, rather zigzag, glabrous. Lenticels pale and small. Pith whitish, small. **Leaf Scars**—Alt. two-ranked, flattened oval. Bundle scars three but often indistinct. Stipular scars unequal. **Buds**—No terminal bud, solitary, reddish-brown, slightly pubescent, eight to nine bud scales visible, somewhat longitudinally striated. **Bud Content**—Stipules broad and scale-like, lvs. simple, whitish hairy, with edges plicate. **Leaf Remnants**—Pinnately veined, oblong-ovate, doubly serrate. **Fruit Remnants**—A ribbed nutlet enclosed in a bladder-like involucre, the staminate catkin usually present over winter. —*O. virginiana* K. Koch.

CORYLUS L. Hazel

Habit—Deciduous shrubs, rarely if ever tree-like. **Twigs**—Slender to moderate, rather zigzag, puberulent to pubescent. Lenticels paler, usually conspicuous. Pith becoming tan, small to moderate, often rather angled in section. **Leaf Scars**—Alt. two-ranked, half round to triangular. Bundle scars three or sometimes more. Stipular scars

long. **Buds**—No terminal bud, brown to gray, obliquely sessile, solitary, obtuse and blunt, ciliate, about ten bud scales visible. **Bud Content**—Leaf long silky-hairy with plicate edges and somewhat conduplicate, bud often sticky inside, red stigma often protruding. **Leaf Remnants**—Ovate to obovate, pinnately veined, coarsely doubly serrate, often rather lobulate. **Fruit Remnants**—A nut surrounded or included by an involucre, the staminate catkin usually present.

1. Bud scales ciliate but sparingly pubescent if at all.
   2. Lobes of the involucre entire or sparingly dentate; buds often over 5 mm. long. —**C. heterophylla* Fisch.
   2. Lobes of the involucre dentate-serrate; buds seldom over 5 mm. long. —**C. Avellana* L.
1. Bud scales ciliate and definitely pubescent, especially on the longer scales.
   3. Third bud scale as long as the bud, the outer scale commonly falling early, not over four bud scales visible; involucre prolonged into a tube; twig slightly if at all pubescent. —*C. cornuta* Marsh.
   3. Third bud scale shorter than the bud, more than four bud scales visible; involucre not prolonged; twig with long glandular hairs. —*C. americana* Marsh.

Family FAGACEAE

Fagus L. Beech

Habit—Deciduous trees, bark gray and smooth. **Twigs**—Rather slender, usually zigzag, gray to brown. Lenticels pale. Pith usually small, often angled, rays of wood prominent. **Leaf Scars**—Alt. two-ranked, half round, not directly beneath the bud. Bundle scars vary, sometimes in threes. **Buds**—Solitary, brownish, often seeming somewhat stalked, elongated and pointed, divergent with sixteen to twenty-four spirally four-ranked bud scales visible. **Bud Content**—Stipules present and resembling scales. Lvs. are simple and densely whitish hairy with plicate edges. Inner scales with translucent edges. **Leaf Remnants**—Often present, simple, ovate to elliptical, pinnately veined, obscurely serrate to dentate. **Fruit Remnants**—A nut in an involucre.

1. Bud scales ciliate on edges and at least somewhat pubescent; end of twig often hairy.
   2. Flat topped, with pendulous branches; end of twig densely hairy. —**F. sylvatica purpurea-pendula* Rehd.
   2. Not flat topped, branches not pendulous; end of twig not densely hairy. —**F. sylvatica* L.
1. Bud scales not ciliate on edges, glabrous; twigs glabrous. —**F. grandifolia* Ehrh.

Castanea Mill. Chestnut

Habit—Deciduous trees with furrowed bark. **Twigs**—Moderate, gray to brown. Lenticels conspicuous, pale and raised. Pith white,

rather large, five-pointed in section. **Leaf Scars**—Alt. two-ranked or appearing more than two-ranked sometimes, half round. Bundle scars three or sometimes more. Stipular scars narrow and unequal. **Buds**—No terminal bud, solitary, rather oblique, two to three scales visible, the outer two-ranked. **Bud Content**—Lvs. between scale-like stipules, vernation straight, the edges a trifle plicate, very brown, hairy. **Leaf Remnants**—Simple, oblong-lanc., spiny-serrate, pinnately veined. **Fruit Remnants**—Nutlets in a spiny involucre.

1. Buds and twigs glabrous or minutely hairy. —**C. dentata* Borkh.
1. Buds heavily short pubescent; twigs pubescent especially near the end. —**C. mollissima* Bl.

Quercus L. Oak

Habit—Deciduous in Iowa, usually trees. **Twigs**—Slender to moderate. Pith whitish to tan, moderate to large, generally five-pointed in section. **Leaf Scars**—Alt. more than two-ranked, half round and raised, tending to crowd out with the lateral buds toward the twig end. Bundle scars small, numerous, scattered. Stipular scars small or absent. **Buds**—Usually solitary, rather clustered near the end of the twig, bud scales usually numerous and five-ranked. **Bud Content**—Usually numerous inner scales which grade into stipules. Lvs. simple, pinnately veined, usually pubescent, vernation various, straight, conduplicate to revolute. Staminate flowers in catkins. **Leaf Remnants**—Often remaining, varying with the species but simple and pinnately veined. **Fruit Remnants**—An acorn, often present partly developed in winter or fallen on the ground beneath.

(Based on twig, fruit, and habit characters)

1. Shrubs, seldom over 2.5 mm. high.
    2. Twigs stout, usually corky winged; acorns with fringed cup. —*Q. macrocarpa* Michx.
    2. Twigs not stout, not corky; acorn cup not at all fringed. —*Q. prinoides* Willd.
1. Typically trees.
    3. Twigs whitish gray, slender and without corky ridges; cup of acorn wholly or almost covering the acorn; very rare in Iowa. —*Q. lyrata* Walt.
    3. Twigs not whitish gray, or if gray with twigs stout and corky ridged; acorn cup more open.
        4. Younger twigs with a yellowish scurf especially on the under side, twigs stout but not corky. —*Q. stellata* Wangh.
        4. No yellow scurf; twigs slender or stout with corky ridges.
            5. Buds definitely downy pubescent over the entire bud surface.
                6. Buds very definitely white or grayish-white downy pubescent, ovoid; twigs glabrous; base of acorn cup obconical. —*Q. velutina* Lam.

6. Buds sparsely downy-pubescent; buds either short and wide or long and conical; twigs usually pubescent; base of acorn cup rounded.
    7. Buds about as broad as long, obtuse; older twigs often corky ridged; scales of acorn cup fringed, the young acorn not on the tree over the winter, inner surface of acorn shell not tomentose. —*Q. macrocarpa* Michx.
    7. Buds long conical, acute; older twigs never corky ridged; acorn cup not fringed, partially developed acorns often present in winter, inner surface of shell tomentose. —*Q. marilandica* Muenchh.
5. Buds glabrous or pubescent only at the margins of the scales or on a part of the bud but not downy over the entire surface.
    8. Buds rounded at tip, usually not over one-half longer than broad.
        9. Bark of older twigs scaling off in layers; acorn cup long stalked with acuminate cup scales. —*Q. bicolor* Willd.
        9. Bark not scaling off on older twigs; acorn cup either not long stalked or if so with scales blunt.
            10. Buds very short, as wide or wider than long, the widest part at the base; acorn with prominently thickened scales but not long-stalked. —*Q. alba* L.
            10. Buds usually a trifle longer than broad, the widest part at the middle; acorn cup either without thickened scales or, if thickened, on a stalked acorn.
                11. Bud scales with lighter, scarious margins; bark of trunk gray, rather scaly. —*Q. Muhlenbergii* Engelm.
                11. Margins of scales not scarious; bark dark and furrowed.
                    12. Bud scales whitish silky ciliate; lvs. with rounded lobes; acorns long stalked. —**Q. robur* L.
                    12. Bud scales not ciliate or only slightly so; leaf lobes sharp; acorns not long-stalked. —*Q. ellipsoidalis* E. J. Hill.
    8. Buds sharp-pointed, usually much longer than broad.
        13. Terminal bud typically over 4 mm. long; acorn over 2 cm. long.
            14. Bud scales darker toward the margins, sometimes pubescent near edges; cup of acorn flat below, acorn sides usually bulging. —*Q. borealis* Michx.
            14. Bud scales uniform in color, usually with scattered hairs over the entire bud; cup of acorn rounded below, its sides not bulging. —*Q. Shumardii* Buchl.
        13. Terminal bud typically 4 mm. or less in length; acorn cup usually less than 2 cm. long.
            14. Young branches often beset with spur-like lateral twigs; lvs. lobed, not revolute in the bud; bud scales not scarious on the margins. —*Q. palustris* L.
            14. Younger branches not having spur-like twigs; lvs. entire, not lobed, revolute in the bud; bud scales often scarious on the margins. —*Q. imbricaria* Michx.

(Based on leaf, twig, and fruit characters)

1. Lvs. with sharp bristle tips at end of leaf or at end of lobes; bark dark; acorns maturing in two seasons, inner surface of acorn shell usually tomentose. (Black Oak Group)
   2. Lvs. with entire, rarely wavy margins, leaf bristle-tipped only at end. —*Q. imbricaria* Michx.
   2. Leaf margins lobed with bristle-tips at end of lobes.
      3. Lvs. broadly wedge-shaped, broad end out, seldom lobed below middle. —*Q. marilandica* Muenchh.
      3. Lvs. not wedge-shaped, broadest part about at middle, lobed below middle.
         4. Leaf lobes usually alternate, often pubescent below; buds woolly when mature; upper scales of acorn cup with flaring tips; inner bark orange-yellow. —*Q. velutina* Lam.
         4. Leaf lobes usually opposite, glabrous beneath except for hairs in axils of veins in some; buds never woolly; scales of acorn cup appressed; inner bark not bright orange-yellow.
            5. Lvs. deeply lobed, often three-fourths the way to mid-rib, most of lobes widest near end of lobe; acorns less than 2 cm. long.
               6. Acorn cup flat, covering acorn less than one-half its length; native to lowlands; base of leaf mostly cuneate, sometimes truncate; lateral buds pointed at tip. —*Q. palustris* L.
               6. Acorn cup obconical at base, usually covering acorn over one-half; native to uplands; lvs. usually truncate at base, sometimes cuneate; lateral buds rounded at tip. —*Q. ellipsoidalis* E. J. Hill
            5. Lvs. lobed less than one-half to midrib, rarely deeper, most of the lobes widest at base of lobe; acorn usually over 2 cm. long.
               7. Acorn cup flat at base, acorn sides usually bulging; bud scales darker toward the margins; leaf lobes usually cut-toothed; common. —*Q. borealis* Michx.
               7. Acorn cup rounded at base, acorn sides not bulging; bud scales uniform in color; lobes of leaf only slightly cut; rather rare in Iowa. —*Q. Shumardii* Buchl.
1. Lvs. lacking bristle tips although sometimes with acute teeth; bark lightish; acorns maturing in one season, inner surface of acorn shell not tomentose (White Oak Group).
   8. Leaf margins large-toothed, wavy or shallowly lobed, the lobes rarely reaching one-half way in to midrib.
      9 Bark of smaller branches loosely peeling; acorn stalked, with scales of cup acuminate at tip. —*Q. bicolor* Willd.
      9. Bark of smaller branches close; acorns various but not both stalked and with acuminate scales as above.
         10. Shrubs, under 2.5 m. high.
            11. Twigs stout, usually corky winged. —*Q. macrocarpa* Michx.
            11. Twigs slender, not corky. —*Q. prinoides* Willd.
         10. Tree-like.

12. Lvs. not lobed, with remote teeth, with main veins all ending in teeth; acorns neither fringed nor stalked. —*Q. muhlenbergii* Engelm.
12. Lvs. usually shallowly lobed; not all main veins ending in the lobe tips; acorns fringed or stalked.
    13. Twigs grayish, sometimes corky; common native tree; acorns not long stalked, cup fringed at top; buds short, about as wide as long. —*Q. marcrocarpa* Michx.
    13. Twigs reddish brown to olive brown, never corky; a cultivated tree rare in Iowa; acorns long stalked, cup not fringed; buds longer than wide. —**Q. robur* L.

8. Lvs. rather deeply lobed, usually over one-half way to midrib.
    14. Lvs. glabrous, lobes rather equal in length and width; scales of acorn cup heavily tuberculate, without fringed tips. —*Q. alba* L.
    14. Lvs. pubescent, below at least, lobes seldom equal; scales of acorn flat, or, if thickened, with long attenuated tips on some.
        15. Young twigs yellow-scurfy, older twigs short-scurfy hairy; acorns small, seldom over 12 mm in diameter, cup not at all fringed. —*Q. stellata* Wang.
        15. Young twigs grayish, older twigs glabrous or nearly so; acorns usually over 12 mm. in diameter, cup more or less fringed.
            16. Leaf lobes often acute; acorn cup almost or completely covering acorn, twigs never corky; a very rare tree in Iowa. —*Q. lyrata* Walt.
            16. Leaf lobes usually obtuse or rounded; acorn cup rarely almost covering acorn; twigs sometimes corky ridged; a very common tree in Iowa. —*Q. macrocarpa* Michx.

The treatment of the oaks in this region in Rehder is not always satisfactory. *Q. Shumardii* Buchl. as considered here is the same as *Q. Schneckii* Britton, and the common red oak *Q. borealis* Michx. in this list is the *Q. rubra* L. of Gray's Manual, seventh edition. The most generally distributed oaks in Iowa are *Q. borealis, Q. macrocarpa, Q. velutina,* and *Q. alba.*

Family ULMACEAE

Ulmus, L. Elm.

Habit—Deciduous trees, bark rough. **Twigs**—Rather slender, often zigzag, sometimes corky, usually pubescent. Pith whitish sometimes becoming tan, small to moderate. **Leaf Scars**—Alt. two-ranked, half round to crescent-shaped or triangular, somewhat raised, slightly to one side of the bud. Bundle scars three or in three groups. Stipular scars unequal, the longer one under the bud. **Buds**—Solitary, rarely collaterally branched, about four to eight bud scales visible in two ranks. **Bud Content**—Lvs. simple, pinnately veined, vernation conduplicate with edges plicate. Flowers in separate thicker buds. **Leaf**

Remnants—Usually oblique at base and doubly serrate, dark green above. **Fruit Remnants**—A compressed nutlet, surrounded by a wing, seldom present.

1. Buds under 2 mm. in length, usually four bud scales visible. —**U. pumila* L.
1. Buds over 2 mm. long, over four bud scales visible.
    2. Buds covered with rusty red hairs; twigs light gray in color. —*U. fulva* Michx.
    2. Buds glabrous or with hairs not rusty; twigs brown to gray-brown.
        3. Branches and older twigs typically with corky ridges or wings.
            4. Buds typically over 5 mm. long, rather long pointed; twigs brown to gray. —*U. racemosa* Thomas.
            4. Buds under 5 mm. long, ovoid; twigs light brown. —**U. japonica* Sarg.
        3. Branches and twigs without corky ridges.
            5. Crown of tree flat and depressed, branches drooping; leaf buds broad, often over 6 mm. wide. —**U. glabra pendula* Rehd.
            5. Crown not flat; leaf buds narrower.
                6. Buds blackish-brown; rarely seen in Iowa, not native.
                    7. Bud scales white-ciliate, appearing woolly-white at end of bud; twigs straw to light brown in color. —**U. foliacea* Gilib.
                    7. Bud scales brown-ciliate, not woolly; twigs brownish to gray-brown. —**U. glabra* Huds.
                6. Buds light brown; native and very common. —*U. americana* L.

ZELKOVA Spach.

Habit—Deciduous, usually trees with short trunks. **Twigs**—Rather slender, light brown, slightly pubescent near ends. Lenticels paler, rather conspicuous. Pith pale, small to moderate, spongy except near the nodes. **Leaf Scars**—Alt., two-ranked, triangular to flattened oval, some raised. Bundle traces three. Stipular scars unequal. **Buds**—Often collaterally multiple, brown, ciliate and sparingly hairy, about four to six bud scales visible in four ranks. **Bud Content**—Lvs. glabrous, ovate, serrate and pinnately veined, vernation conduplicate. **Leaf Remnants**—Ovate to oblong, oblique-rounded at base, sharply serrate. **Fruit Remnants**—A drupe, wingless. —*Z. serrata* Mak.

Another species *Z. sinica* Schneid. may be present, differing in its more definitely pubescent twigs and buds, but both are very rarely planted here.

CELTIS L. Hackberry

Habit—Deciduous trees with bark becoming warty and gnarled. **Twigs**—Slender, reddish-brown. Lenticels scattered, slightly raised.

Pith white, rather small, finely chambered at nodes. **Leaf Scars**—Alt. about two-ranked, triangularly oval. Bundle scars three or as a confluent group. Stipular scars narrow. **Buds**—No terminal bud, about 3 mm. long, dark brown, appressed, four bud scales visible in two ranks. **Bud Content**—Stipules as scales, lvs. glabrous with straight vernation. **Leaf Remnants**—Simple, ovate, long-acuminate, palmately veined. **Fruit Remnants**—A drupe, reddish to purple, about seven to ten mm. long. —*C. occidentalis* L.

Family MORACEAE

Morus L. Mulberry

Habit—Deciduous trees with bark rather scaly. **Twigs**—Slender to moderate, sometimes with milky sap, gray to brownish, puberulent. Lenticels usually conspicuous. Pith whitish, moderate to large. **Leaf Scars**—Alt. two-ranked, oval flattened on the top, raised, running about parellel with the twig. Bundle scars many, scattered or in a ring. Stipular scars narrow, unequal. **Buds**—Terminal bud lacking, usually solitary, brownish, appressed or spreading, four to five bud scales visible in two ranks. **Bud Content**—Vernation of leaves straight. Flowers, if present, globose clusters in the axil of the lvs. **Leaf Remnants**—Simple, ovate, serrate-dentate, often with rounded lobes, palmately veined. **Fruit Remnants**—A syncarp of achenes.

1. Buds large, often up to 6 mm. long, usually spreading. —*M. rubra* L.
1 Buds smaller, rarely over 5 mm. long, appressed.
   2. Bud scales conspicuously darkened at margins, twigs gray to yellowish. —**M. alba tatarica* Loud.
   2. Bud scales only slightly darkened at margins, twigs gray, reddish to brown.
      3. Twigs gray to brownish tan, a fairly common, rather large tree. —**M. alba* L.
      3. Twigs gray to reddish brown; usually a small tree, rarely planted here. —**M. nigra* L.

Maclura Nutt. Osage-Orange

Habit—Deciduous trees with furrowed, rather orange colored bark, the exposed roots very bright orange. **Twigs**—Rounded or three-sided, rather zigzag, commonly with dwarf branches, glabrous, commonly spiny, the spine being lateral to bud, with milky sap usually evident when twig is cut. Pith whitish, large. Heartwood becoming yellow. **Leaf Scars**—Alt. more than two-ranked, oval to half round, somewhat raised. Bundle traces vary, usually more than three, scattered, in a ring or in three groups. Stipular scars small or small stipules re-

main. **Buds**—Small, often collaterally branching, flattened from the end to appear partly concealed, terminal bud not evident, four to five bud scales visible. **Bud Content**—Too small to make out detail. **Leaf Remnants**—Long-elliptical, acuminate, entire, pinnately veined, with milky sap often evident. **Fruit Remnants**—A large globose syncarp of drupelets, often over 10 cm. in diameter.

—?**M. pomifera* Schneid.

A thornless variety *M. pomifera inermis* Schneid. is occasionally planted.

Family ARISTOLOCHIACEAE

ARISTOLOCHIA L. Birthwort; Dutchmans Pipe

Habit—Deciduous, softwooded twiners. **Twigs**—Greenish, terete but swollen at the nodes. Lenticels not conspicuous. Pith rather large, whitish. Wood ducts and rays prominent. **Leaf Scars**—Alt. U- to horseshoe-shaped. Bundle scars three. Stipular scars none. **Buds**—Superimposed, almost concealed in a downy, olive-colored patch of hairs. **Bud Content**—Lvs. broadly ovate to heart-shaped, vernation straight or nearly so. **Leaf Remnants**—Base of petiole covers most of bud. Lvs. ovate, rather cordate at base, entire, palmately veined, petiole 4 to 5 cm. long. **Fruit Remnants**—A 6 ribbed capsule 6 to 8 cm. long.

1. Twigs tomentose especially near the ends. —**A. tomentosa* Sims.
1. Twigs glabrous. —**A. durior* Hill.

Family CERCIDIPHYLLACEAE

CERCIDIPHYLLUM Sieb. & Zucc. Katsura-Tree

Habit—Small deciduous trees. **Twigs**—Slender, gray to gray brown, glabrous. Lenticels rather conspicuous, becoming transversely elongated. Pith greenish to white, rather small. **Buds**—No terminal bud, laterals solitary, reddish to brown, glabrous, with two bud scales visible, the first one next to the twig and almost the length of the bud. **Bud Content**—Inner scales rose colored. Lvs. ovate, cordate at base, palmately veined, the edges with yellow glands on teeth, vernation involute. Stipules present. **Leaf Remnants**—Ovate, crenate-serrate, glabrous. **Fruit Remnants**—A pod, many seeded, 1.5 to 2 cm. long. —**C. japonicum* Sieb. & Zucc.

Family RANUNCULACEAE

PAEONIA L. Peony

Habit—Small, rather unsymmetrical, deciduous shrubs. **Twigs**—

Stout, gray to light brown, glabrous. Finely black-dotted under a lens. Pith large, becoming yellow-brown. **Leaf Scars**—Alt. more than two-ranked, half round to triangular, large, somewhat raised. Bundle scars about seven in a U-shape with a larger one in the center of the leaf scar. Stipular scars none. **Buds**—No terminal bud, laterals large, often 18 mm., solitary, brown to rosy pink near end, with nine to eleven bud scales visible in many ranks, keeled and attenuated under the tip of scale. **Bud Content**—Lvs. appear compound or deeply lobed, the vernation of the parts convolute, petiole base wide. Flower when present solitary, surrounded by lvs. **Leaf Remnants**—Large, bipinnate. **Fruit Remnants**—A pubescent follicle.

—**P. suffruticosa* Andr.

ZANTHORHIZA L'Herit. Yellow-root

Habit—Small deciduous, sparingly branched shrubs. **Twigs**—Gray to gray brown, glabrous. Lenticels not conspicuous. Pith rather large, lemon-yellow like the wood. Wood rays prominent. **Leaf Scars**—Alt., more than two-ranked, shallowly U-shaped, almost encircling the twig. Bundle traces eleven to twelve. Stipular scars lacking. **Buds**—Greenish-gray to yellow-brown, the terminal bud large, with mucronate tips, about four visible scales, glabrous but somewhat ciliate. **Bud Content**—Inner scales with leaf-like structure at tip. Lvs. pinnately compound, with three serrate lfts., base broad, glabrous, vernation of lfts. convolute. Flowers when present at the side of the leaf cluster. **Leaf Remnants**—Pinnately compound with five incised lfts. **Fruit Remnants**—In racemes, follicles one seeded.

—**Z. apiifolia* L'Herit.

CLEMATIS *L.* Virgins Bower

Habit—Soft wooded, climbing by petiole tendrils. **Twigs**—Ridged. Lenticels not conspicuous. Pith moderate, angled because of cavities in cortex, continuous except for a thin plate at the node. **Leaf Scars**—Petioles persistent, opposite, connected by a ridge. Stipular scars none. **Buds**—No terminal bud, small, solitary, pubescent, four to six scales visible in four ranks, outer keeled. **Bud Content**—Lvs. appearing three-lobed or ternate, small. **Fruit Remnants**—Globose head of achenes with plumose styles.

1. Twigs gray to straw-colored, with twelve angles, and heavy pubescence; lvs. if present compound, of three to five entire lfts., none simple.

—**C. paniculata* Thunb.

1. Twigs light brown to reddish-brown or gray-brown, glabrous or finely pubescent; lvs., if present, with incised lfts., or entire with some of the upper ones simple.
   2. Twigs reddish-brown; some of the upper lvs. simple with entire margins; never native. —**C. Jackmani* Th. Moore.
   2. Twigs brown to light gray-brown; lvs., if present, compound with three incised lfts.; often native.
      3. Stems woody only at base; rather common. —*C. virginiana* L.
      3. Stems woody throughout; very rare in Iowa. —*C. verticillaris* DC.

Two other species of Clematis are found in Iowa, *C. texensis* Buckl. a cultivated vine and *C. Pitcheri* T. & G., a native plant. They seldom, if ever, become woody here and for that reason are not included in the key.

Family BERBERIDACEAE

MAHONIA Nutt.

Habit—Evergreen shrubs. **Twigs**—Rather stout, grayish-tan to straw-colored, slightly puberulent. Lenticels inconspicuous. Pith pale, large. Medullary rays of wood large. **Leaf Scars**—Alt., two or more ranked, narrow, half encircling the stem, little raised. Bundle scars eight to nine. Stipular scars lacking. **Buds**—Brown to greenish, four or five scales visible which often have three spine-like structures at the tip or two with a scar between. **Bud Content**—Scales grade into lvs. which have broad, flat bases, two stipules at sides, pinnately compound leaf with weakly conduplicate lfts. **Leaf Remnants**—About seven lfts., thick, and spiny-edged. **Fruit Remnants**—Bluish black, bloomy berry about 8 mm. wide.

—**M. Aquifolium* Nutt.

BERBERIS L. Barberry

Habit—Deciduous shrubs. **Twigs**—Slender with angles or ridges below the leaf scars, reddish-brown to gray, glabrous, one to three spines below the leaf scars. Lenticels not conspicuous. Pith moderate and yellow like the wood. **Leaf Scars**—Alt., more than two-ranked, half round, grouped on a short shoot terminated by the bud. Bundle scars three, often indistinct. No stipular scars. **Buds**—Solitary, ovoid, glabrous, six to ten scales visible, outer with scars at the end. **Bud Content**—Scales grade into lvs., green and glabrous with straight vernation. **Leaf Remnants**—Often present, simple, pinnately veined, narrow, cuneate. **Fruit Remnants**—Often present, a red to purplish berry.

1. Twigs gray; thorns often three at a node. —**B. vulgaris* L.
1. Twigs reddish brown; thorns usually one at a node. —**B. Thunbergii* DC.

Family MENISPERMACEAE

MENISPERMUM L. Moonseed

Habit—Deciduous twiners. **Twigs**—Rather slender, fluted, straw-colored, glabrous. Lenticels not conspicuous. Pith white, very large, fluted or angled. Vascular strands show as enlarged structures below angles in the twig. **Leaf Scars**—Alt., oval or elliptical, concave, a line or tear extending down from the top, raised and parallel to the twig. Bundle scars seven, often in three groups. No stipular scars. **Buds**—Superimposed, with the lower covered by the scar, straw-colored to brownish-red with two to three obtuse, hairy, small, short visible scales. **Bud Content**—Too small to make out. **Leaf Remnants**—Petioles long, lvs. orbicular, ovate, cordate and somewhat pelate, palmately veined, entire. **Fruit Remnants**—A blue-black drupe 8 mm. in diameter with a ring-like or crescent-shaped stone.

—*M. canadense* L.

Family MAGNOLIACEAE

MAGNOLIA L. Magnolia

Habit—Deciduous or sometimes half evergreen trees or shrubs. **Twigs**—Rather aromatic, stout, with conspicuous terminal flower buds usually present. Lenticels pale. Pith large, sometimes diaphragmed. **Leaf Scars**—Alt., two- or more than two-ranked, broadly crescent, oval or U-shaped, little raised. Bundle traces many, often scattered. Stipular scars as a linear line encircling the twig. **Buds**—Solitary, ovoid or fusiform, terminal usually enlarged, one bud scale formed at the back. **Bud Content**—Under the two outer connate stipules is a conduplicate leaf, then two more stipules and another leaf. In the flower buds the flower is in the center of the lvs., flower parts often large, many stamens and pistils. **Leaf Remnants**—Simple, pinnately veined, entire. **Fruit Remnants**—Cone-like and of dehiscent carpels.

1. Leaf scars clustered at the swollen places on the twig; terminal bud acuminate, usually over 30 mm. long, glabrous.
   2. Young lvs. in the bud with cordate, auriculate base. —**M. Fraseri* Walt.
   2. Young lvs. in the bud with long cuneate base. —**M. tripetata* L.
1. Leaf scars scattered; terminal bud not elongately pointed, rarely 25 mm. long, hairy or glabrous.
   3. Deciduous or half evergreen; pith sometimes with diaphragms; terminal bud under 10 mm. long, silky short-hairy or glabrous. —**M. virginiana* L.

3. Deciduous; pith never with diaphragms; terminal bud usually over 10 mm. long, especially flower buds; hairs on bud coarse.
    4. Leaf scars definitely U- or V-shaped, surrounding the bud over one-half; flower buds not swollen at middle. —**M. acuminata* L.
    4. Leaf scars crescent-shaped, not surrounding the bud over one-half; flower buds swollen at middle.
        5. Young twigs greenish beneath pubescence; leaf buds and lateral buds only slightly hairy. —**M. kobus* Thunb.
        5. Young twigs reddish-brown beneath hairs; leaf buds and lateral buds coarse-hairy. —*X *M. Soulangeana* Soul.

LIRIODENDRON L. Tulip-tree

Habit—Deciduous trees with ridged bark. **Twigs**—Rather stout, glabrous, reddish brown, smooth, rather aromatic and bitter tasting. Lenticels pale, elongated, conspicuous. Pith white, moderate, continuous but with firmer diaphragms. **Leaf Scars**—Alt. more than two-ranked, almost round, slightly raised, large. Bundle scars in a scattered obscure ring. Stipular scars narrow and encircling the twig. **Buds**—Solitary or superimposed, reddish brown, often glaucous, terminal bud flattened, blunt and appearing stalked, two bud scales visible. **Bud Content**—Beneath the two connate scales is a leaf with a broad truncate apex, vernation conduplicate and reclinate. Then a series of two more scales and another leaf, etc. **Leaf Remnants**—Simple, rather square in shape. **Fruit Remnants**—A spindle-like column, usually present, upon which the winged carpels were crowded. —**L. Tulipifera* L.

Family CALYCATHACEAE

CALYCANTHUS L. Allspice

Habit—Deciduous shrubs. **Twigs**—Moderate, two-angled or ridged from each leaf scar, dark reddish-brown, short-hairy. Lenticels pale, rather conspicuous. Pith white, moderate to large, round or six-angled in section, odor rather spicy. **Leaf Scars**—Opp., U- to horseshoe-shaped. Bundle scars two. Stipular scars none but opposite leaf scars connected by a transverse ridge. **Buds**—No terminal bud, laterals small, partly concealed, bud scales indistinct, silky hairy. **Bud Content**—Lvs. with straight vernation. **Leaf Remnants**—Elliptical, entire, pinnately veined, lighter and densely short hairy beneath. **Fruit Remnants**—An urn-like receptacle 6 to 7 cm. long containing ovoid achenes. —**C. floridus* L.

Family ANNONACEAE

ASIMINA Adans. Pawpaw

Habit—Small deciduous trees. **Twigs**—Moderate, often a trifle zigzag, reddish brown. Lenticels inconspicuous. Pith white, rather small, becoming partitioned by inconspicuous green diaphragms. Bark of twig tough. **Leaf Scars**—Alt., two-ranked, horseshoe- to U-shaped. Bundle scars commonly five. Stipular scars none. **Buds**—Terminal bud flat, elongated, densely covered with silky dark brown hairs, no evident bud scales, some of laterals globose. **Bud Content**—Lateral globose flower buds contain flowers with three sepals, three petals, many stamens in a ball near the top and six pistils in the center. **Leaf Remnants**—Obovate, entire, cuneate, with acuminate tip. **Fruit Remnants**—An oblong, fleshy berry. —*A. triloba* Dun.

Family LAURACEAE

SASSAFRAS Nees. Sassafras

Habit—Deciduous trees with bark deeply furrowed into flat ridges, separated by narrow horizontal cracks. **Twigs**—Stout to slender, greenish to reddish brown, glabrous and glaucous near the end. Lenticels dark, not very conspicuous. Pith pale, moderate, sometimes five-angled. Odor of twigs and roots aromatic. **Leaf Scars**—Alt., more than two-ranked, half round, somewhat raised. Bundle scars one as a transverse line, sometimes broken. Stipular scars none. **Buds**—Solitary, greenish to brown, with four to five bud scales visible, which are somewhat keeled. **Bud Content**—Inner scales silky-hairy and grading into the leaves, these being hairy on the back with straight vernation. **Leaf Remnants**—Ovate, entire, often three-lobed and obovate. **Fruit Remnants**—A drupe.

—**S. officinale* Nees & Eberm.

Family SAXIFRAGACEAE

PHILADELPHUS L. Mock Orange

Habit—Deciduous shrubs. **Twigs**—Slender, six- to eight-angled, the bark soon peeling off in small plates, usually reddish-brown. Lenticels not conspicuous. Pith white, moderate to large. **Leaf Scars**—Opposite, crescent to half-round in shape, often broken at tip by the bud, raised. Bundle scars three, these sometimes U- or C-shaped. Stipular scars none but opposite leaf scars connected by a transverse ridge. **Buds**—Solitary, small, often partially concealed by leaf scar, about two to three somewhat pubescent bud scales visible. **Bud**

Content—Lvs. valvate, boat-shaped but with straight vernation. **Leaf Remnants**—Simple, remotely serrate, pinnately veined. **Fruit Remnants**—Often present, a four-valved capsule.

This is a genus with well marked winter characters but with the species almost impossible to distinguish in any condition. X *P. Lemoinei* seems rather definite and differs from the other forms collected, by its short hairy twigs. No species key was attempted.

DEUTZIA Thunb. Deutzia

Habit—Deciduous shrubs. **Twigs**—Moderate to slender, often rather angled, stellate-pubescent, bark usually exfoliating finally. Pith small to large, white or brown, spongy or excavated in center between the nodes. **Leaf Scars**—Opp., V- to crescent-shaped, slightly raised. Bundle scars three. No stipular scars but opposite leaf scars connected by a transverse ridge. **Buds**—Solitary or collaterally branched, slightly stellate-scurfy with four to ten bud scales visible in four ranks, the outer keeled and often attenuated. **Bud Content**—Scales grade into lvs. which are pinnately veined, simple, vernation straight but the leaf keeled. Flowers in a cone-shaped cluster in center of leaves. **Leaf Remnants**—Serrate, stellate-hairy on one side at least, pinnately veined. **Fruit Remnants**—Three- to five-valved capsule.

1. Pith brownish; bud scales short attenuated. —**D. scabra* Thunb.
1. Pith whitish; bud scales long attenuated.
   2. Twigs not angled; lvs if present stellate only above. —**D. gracilis* Sieb & Zucc.
   2. Twigs six-angled from the leaf scar; lvs. stellate on both sides. —*X *D. Lemoinei* Lemoine

HYDRANGEA L. Hydrangea

Habit—Deciduous shrubs or small trees. **Twigs**—Moderate to stout, soft-wooded, often straw-colored. Lenticels not conspicuous. Pith large, white. **Leaf Scars**—Opposite or whorled, crescent-shaped, very little raised. Bundle scars three. Stipular scars lacking but opposite leaf scars connected by transverse ridges. **Buds**—Straw to brown, six to eight bud scales visible in four ranks, solitary. **Bud Content**—Lvs. valvate with straight vernation. **Fruit Remnants**—A capsule but remnants of flower usually present in a panicle or corymb.

1. Buds short, conical, at about right angles to the twig; leaf scars often whorled; inflorescence remains elongated. —**H. paniculata* Sieb.
1. Buds ovoid, not so spreading; leaf scars rarely whorled; inflorescence remains rather flat topped. —*H. arborescens* L.

RIBES L. Currant; Gooseberry

Habit—Deciduous shrubs. **Twigs**—Usually moderate and somewhat ridged or angled, epidermis quickly shredding, often with prickles, especially at the nodes. Pith whitish, at least at first, usually moderate, becoming spongy. **Leaf Scars**—Alt., more than two-ranked, U- or V-shaped to crescent, slightly raised. Bundle scars three. Stipular scars none. **Buds**—Solitary, often becoming stalked, ovoid or lanceoloid with about five to eight usually keeled bud scales visible. **Bud Content**—Lvs. with broad flat base. Flowers in center of lvs. with five sepals. **Leaf Remnants**—Simple, palmately veined and lobed. **Fruit Remnants**—A berry, rarely present.

1. Thorns or prickles present at some of the nodes.
   2. Cult. in gardens for fruit; not native. —**R. Grossularia* L.
   2. Not cultivated for fruit ordinarily; found native. Three species seem to fall here, indistinguishable in winter condition and showing intergradations in any condition.
      —*R. Cynosbati* L., —*R. missouriensis* Nutt., —*R. oxyacanthoides* L.
1. No thorns or prickles.
   3. Bud scales and often the twig with sessile, yellow resin-dots or glands.
      —**R. nigrum* L.
   3. No yellow glands present.
      4. Twigs gray-tomentose. —**R. odoratum* Wendl.
      4. Twigs glabrous to short puberulent.
         5. Buds downy-pubescent, especially near the ends. —**R. sativum* Syme.
         5. Buds glabrous or puberulent.
            6. Twigs and buds glabrous. —**R. alpinum* L.
            6. Twigs and usually the buds short, puberulent, ciliate.
               7. Native; twigs puberulent. —*R. americanum* Mill.
               7. Cultivated, not native; twigs glabrous.
                  8. Terminal bud obtuse, reddish-brown. —**R. aureum* Pursh.
                  8. Terminal bud acute, light brown to gray.
                     —**R. petraeum* Wulf.

R. missouriense is here considered to be the same plant at *R. gracile* of Gray's Manual, seventh edition, and *R. americanum* the same as *R. floridum*. The taxonomy of this genus is somewhat confused.

In addition to the species listed in the key *R. glandulosum* Grauer., a prostrate or reclining currant, has been reported somewhat doubtfully from Dubuque County.

Family HAMAMELIDACEAE

LIQUIDAMBAR L. Sweet Gum

Habit—Deciduous, rather conical trees, bark dark, furrowed. **Twigs**—Moderate to stout, often with corky ridges, often developing short spur-like twigs. Lenticels light, rather conspicuous. Pith pale, be-

coming brown, moderate, rather five-angled and spongy. **Leaf Scars**—Alt., more than two-ranked, half round. Bundle scars three. Stipular scars none. **Buds**—Solitary, reddish-brown, sometimes appearing stalked, short ciliate, about eight to nine rather apiculate bud scales visible. **Bud Content**—Lvs. deeply lobed with conduplicate, serrate, acuminate lobes. Stipules at side of leaf. **Leaf Remnants**—With five to seven lobes, like a star. **Fruit Remnants**—Capsules in long stalked globose clusters, seeds winged. —**L. Styraciflua* L.

The corky ridges on the bark of this species were described by Gregory in 1888 (22).

HAMAMELIS L. Witch-Hazel

Habit—Deciduous shrubs or small trees. **Twigs**—Rather slender, zigzag. Lenticels not conspicuous. Pith pale, moderate. **Leaf Scars**—Alt. usually two-ranked, rather triangular. Bundle scars usually three but sometimes more or less. Stipular scars unequal, separated from leaf scar. **Buds**—Solitary, hairy, naked except for two lateral stipules which often remain, stalked. **Bud Content**—Lvs. conduplicate, edges appearing plicate, very hairy. Flowers present all winter outside the bud, but often closed, perianth parts in four, with four stamens, one ovary and two styles. **Leaf Remnants**—Oblong to obovate, simple, pinnately veined, somewhat stellate-hairy on the veins below. **Fruit Remnants**—Often present, a two-valved, two-seeded capsule, the seeds black.

1. Flowers opening in the autumn, remaining open all winter; terminal bud often over 7 mm. long. —*H. virginiana* L.
1. Flowers remaining closed until spring; terminal bud usually less than 7 mm. long. —**H. vernalis* Sarg.

Family EUCOMMIACEAE

EUCOMMIA Oliv.

Habit—Deciduous, becoming trees. **Twigs**—Moderate, rather zigzag, reddish-brown with a gray scurf often present. Lenticels paler and somewhat elongated, rather conspicuous. Pith white, rather large, becoming chambered. Inner bark with rubbery strands. **Leaf Scars**—Alt., two- or more than two-ranked, half-elliptical. Bundle scar one, rather U-shaped. Stipular scars none. **Buds**—Reddish-brown, about six ciliate bud scales visible. **Bud Content**—Inner scales grade into ovate, serrate, pinnately veined lvs., the vernation straight but the lvs. wrapped around the inner mass. **Leaf Remnants**—Ovate to oblong, about six pairs of veins. **Fruit Remnants**—A compressed, one-seeded, winged nutlet. —**E. ulmoides* Oliv.

Family PLATANACEAE

PLATANUS L. Buttonwood; Sycamore; Plane-tree

Habit—Deciduous trees, bark dark-brown, furrowed at the base of the trunk, the ridges with plate-like scales, higher on the trunk peeling off and exposing the conspicuous whitish to yellowish inner bark. **Twigs**—Moderate to slender, glabrous. Lenticels small, pale. Pith pale, rather large. Wood rays conspicuous. **Leaf Scars**—Alt., usually two-ranked, horseshoe-shaped, almost surrounding the bud. Bundle scars five to eight. Stipular scars as a ring encircling the entire twig. **Buds**—No terminal bud, laterals solitary, conical, brownish, glabrescent, covered by one bud scale. **Bud Content**—Rather resinous and sticky. Lvs. simple, tan-woolly, with plicate vernation. **Leaf Remnants**—Simple, palmately lobed and veined. **Fruit Remnants**—A globose syncarp about 2.5 cm. in diameter bearing nutlets.

—*P. occidentalis* L.

The two other species may be looked for in cultivation and are sold by nurseries, but no specimen examined was in proper condition for accurate identification.

Family ROSACEAE

PHYSOCARPUS Maxim.

Habit—Deciduous, loosely branching shrubs. **Twigs**—Rather slender, two- or three-ridged from below each leaf scar, the older twigs with bark shredding. Lenticels not conspicuous. Pith tan, moderate. **Leaf Scars**—Alt., two- or more than two-ranked, crescent to somewhat three-lobed in shape, raised, forming a shelf for the bud base. Bundle scars five, the lower larger. **Buds**—Solitary, appressed, rather small, about five to ten brownish scales visible in several ranks. **Bud Content**—Lvs. hairy-white, vernation conduplicate to plicate edged. **Leaf Remnants**—Broad-ovate, margins crenate, palmately veined and lobed. **Fruit Remnants**—Of three to five brown follicles.

1. Follicles glabrous; twigs and buds moderate in size, the twigs often 2 mm. in diameter; buds often over 3.5 mm. long. —*P. opulifolia* Maxim.
1. Follicles pubescent; twigs and buds slender and smaller —*P. intermedius* Schneid.

STEPHANANDRA Sieb. & Zucc.

Habit—Small, loosely branched, deciduous shrubs. **Twigs**—Slender, zigzag, glabrous, straw to light brown. Bark of twig somewhat fissured. Lenticels inconspicuous. Pith pale to light brown, small to moderate. **Leaf Scars**—Alt., two-ranked, triangular to crescent-

shaped, little raised. Bundle scars three. Stipular scars rather large. **Buds**—Small, commonly superimposed, the uppermost larger, brownish, ciliate, about four bud scales visible, the outer keeled. **Bud Content**—Lvs. ovate and lobed, vernation straight. Stipules at sides of leaves. **Leaf Remnants**—Simple, lobed, serrated margins. **Fruit Remnants**—Of follicles in terminal panicles. —**S. incisa* Zabel.

SPIRAEA L. Spirea

Habit—Deciduous shrubs. **Twigs**—Usually slender and rather zigzag, often ridged from the leaf scars. Lenticels inconspicuous. Pith pale to brown, moderate to large. **Leaf Scars**—Alt., more than two-ranked, half-round, often much raised, forming a shelf for the bud. Bundle scar one. No stipular scars. **Buds**—Small, solitary or occasionally collaterally branched, globose to lanceoloid. **Bud Content**—Scales grade into simple lvs. with straight vernation, the ends sometimes pinched together. **Leaf Remnants**—Simple, margins dentate, serrate or lobed. **Fruit Remnants**—Follicles in umbels, corymbs or panicles.

1. Twigs terete or two ridged for only a very short distance below the leaf scar; buds spreading; twigs glabrous.
   2. Buds widest at or just below the middle; twigs sometimes with short ridges. —*X *S. Vanhouttei* Zabel.
   2. Buds broadest at or near base; twigs not at all ridged.
      3. Twigs usually reddish brown to gray; lvs. if present sub-orbicular, obtuse and palmately veined. —**S. trilobata* L.
      3. Twigs deep reddish brown; lvs. if present rhombic-lanceolate, acute, pinnately veined. —**S. catoniensis* Lour.
1. Twigs definitely two or three ridged for some distance below the leaf scar; buds appressed or spreading; twigs glabrous or pubescent.
   4. Buds acuminate, the points bent toward the twig.
      5. Twigs strongly three ridged from below each scar; buds large, often over 4 mm. long; fruits in an elongated panicle. —*S. salicifolia* L.
      5. Twigs moderately two ridged from below the scars, rarely faintly three ridged; buds shorter; fruits in a flat topped corymb. —*X *S. bumalda* Burenich.
   4. Buds acute to obtuse, tips not bent.
      6. Buds heavily tomentose near end; young twigs heavily pubescent.
         7. Branches reddish brown; accessory collateral buds common; fruits in a sessile umbel, usually not present. —**S. prunifolia* Sieb. & Zucc.
         7. Branches light brown to gray; accessory buds seldom present; fruit remnants usually present as an elongated panicle.
            8. Twigs glabrous or nearly so; buds sparingly pubescent near tip. —**S. alba* Dur.
            8. Twigs definitely pubescent; buds pubescent.

9. Twigs rusty tomentulose; follicles hairy. —*S. tomentosa* L.
9. Twigs gray tomentose; follicles glabrous. —*X *S. Billiardii* Herinicq.
6. Buds glabrous or ciliate to puberulent; twigs glabrous to tomentose.
10. Young twigs heavily tomentose; lvs. when present linear. —**S. Thunbergii* Sieb.
10. Young twigs glabrous to puberulent; lvs. not linear.
11. Follicles borne in a terminal panicle which generally persists.
12. Twigs reddish brown; pedicels of inflorescence glabrous. —**S. latifolia* Borkh.
12. Twigs light brown to gray brown; pedicels of inflorescence pubescent.
13. Pith becoming orange brown; native as well as cult. —*S. salicifolia* L.
13. Pith pale; not native. —**S. alba* Dur.
11. Follicles borne in a simple umbel or umbel-like raceme.
14. Twigs reddish brown on young growth, internodes often short. —**S. hypericifolia* L.
14. Twigs straw to gray tan on young growth, internodes not usually short. —**S. chamaedryfolia* L.

SORBARIA A. Br. Sorbaria

Habit—Deciduous shrubs. **Twigs**—Rather stout, often zigzag, straw-gray to brownish-gray. Lenticels large, conspicuous. Pith large, brown. **Leaf Scars**—Alt., obscurely two-ranked, half round, oval to triangular, large, little raised. Bundle scars three. Stipular scars none. **Buds**—Terminal bud lacking, laterals solitary or collaterally branched, ovoid, brownish to red, often green at tip, about four to six keeled bud scales visible. **Bud Content**—Lvs. pinnately compound, the lfts. serrate, with conduplicate vernation. Stipules broad. **Leaf Remnants**—About thirteen to twenty-three lfts. **Fruit Remnants**—Follicles in a panicle.

1. Twigs very zigzag; remains of inflorescence a panicle with spreading branches. —**S. arborea* Schneid.
1. Twigs only moderately zigzag; remains of inflorescence with upright branches. —**S. sorbifolia stellipila* Maxim.

EXOCHORDA Lindl.

Habit—Deciduous shrubs. **Twigs**—Rather slender, grayish-brown, glabrous. Lenticels pale, rather elongated. Pith white, moderate, sometimes slightly spongy. **Leaf Scars**—Alt., more than two-ranked, narrowly V-shaped. Bundle scars three. Stipular scars none. **Buds**—Solitary, brownish, edges of scales rather translucent, terminal bud with about eight to twelve somewhat keeled scales. **Bud Content**—Flower cluster in center of lvs. when present. Lvs. long-acuminate,

green, glabrous with straight vernation. **Leaf Remnants**—Simple, entire or serrulate, cuneate base, mucronate apex, pinnately veined with about four pair of veins. **Fruit Remnants**—Broad turbinate capsule 8 to 10 mm. long. —**E. racemosa* Rehd.

COTONEASTER Med. Cotoneaster

Habit—Shrubs, commonly deciduous. **Twigs**—Slender to moderate, often ridged beneath the leaf scar, pubescent especially near ends, reddish-brown usually. Pith pale, sometimes becoming brown. **Leaf Scars**—Alt., more than two-ranked, half-round or half-oval, distinctly raised, forming a shelf on which the base of the bud rests. Bundle scar one. Stipules present at top of scar or often broken or partly broken off. **Buds**—Only two definite bud scales, these lateral, about three-fourths the length of the bud and sparingly hairy, exposing the woolly bud end. **Bud Content**—Stipules with lvs. between, these entire, woolly, pinnately veined, vernation conduplicate to somewhat convolute. **Leaf Remnants**—Rather small, to 3 cm. long, shiny above, entire. **Fruit Remnants**—A small pome in cymes.

1. Twigs two-ridged for some distance below each leaf scar; fruit red. —**C. divaricata* Rehd. & Wils.
1. Twigs not ridged or ridged for a very short distance only; fruit red or black.
    2. Twigs dark purplish-black beneath hairs; fruit purplish-black. —**C. nitens* Rehd. & Wils.
    2. Twigs reddish-brown beneath hairs; fruit reddish to black.
        3. Fruit purplish-black; young twigs light reddish-brown; common. —**C. acutifolia* Turcz.
        3. Fruit reddish; young twigs dark reddish-brown; rare.
            4. Lenticels pale, conspicuous. —**C. multiflora* Bge.
            4. Lenticels dark, not conspicuous. —**C. racemiflora* K. Koch.

CRATAEGUS L. Haw

Habit—Deciduous trees or sometimes shrubs. **Twigs**—Moderate to stout, usually with smooth thorns at some of the nodes, usually glabrous. Pith white, moderate to rather large. **Leaf Scars**—Alt., more than two-ranked, narrow reniform to crescent shaped, somewhat raised. Bundle scars three. Stipular scars small if present. **Buds**—Solitary, lateral buds rounded at the tip, glabrous or very slightly ciliate, four to eight rather thick bud scales visible. **Bud Content**—Scales grade into lvs. which are between two stipules, vernation straight with edges often plicate or leaf lobed with conduplicate lobes. **Leaf Remnants**—Deeply serrate-dentate, usually lobulate. **Fruit Remnants**—A small pome with one to five bony carpels, usually borne in corymbs.

This genus has fairly well marked winter characteristics especially if the thorns are present. The species in this state are still in an uncertain position. A few like *C. mollis* Scheele., *C. crus-galli* L., *C. punctata* Jacq., and *C. macracantha* Lodd. are fairly definite among the native species. In the introduced group *C. Oxyacantha* L., *C. monogyna* Jacq., and *C. pinnatifida* Bge. have been located in the present study. However, the majority of our plants are almost impossible for anyone not a specialist in the group to name. For this reason no species key is attempted.

SORBUS L. Mountain-Ash

Habit—Deciduous trees, bark tending to remain smooth. **Twigs**—Moderate, lenticels large, elongated, conspicuous. Pith becoming brown, moderate. **Leaf Scars**—Alt., more than two-ranked, crescent- to linear-shaped, definitely raised. Bundle scars three to five or rarely seven. No stipular scars. **Buds**—Solitary, the terminal bud enlarged with about three to five bud scales visible. **Bud Content**—Bud scales grade into lvs. which are pubescent, pinnately compound or lobed, the lfts. conduplicate. Stipules present. **Leaf Remnants**—Pinnately compound at least near the base. **Fruit Remnants**—Small pomes borne in corymbs.

1. Buds distinctly gummy, not densely woolly, although somewhat pubescent. —? **S. americana* Marsh.
1. Buds not gummy, densely woolly at least near the tip.
   2. Bundle scars three or, if five, with the second and fourth ones smaller; twigs often woolly near end; buds greenish at base. —* X *S. hybrida* L.
   2. Bundle scars five, all equal; twigs seldom woolly; buds dark brown. —**S. Aucuparia* L.

S. americana has been reported as native in Iowa but may have been an escape. *S. Aucuparia* is by far the most common species in cultivation in Iowa.

ARONIA Pers. Chokeberry

Habit—Deciduous shrubs. **Twigs**—Slender, brownish-red beneath a gray skin. Lenticels usually large. Pith whitish, moderate. **Leaf Scars**—Alt., two- or more than two-ranked, flattened U- or V-shaped. Bundle scars three. No stipular scars. **Buds**—At least the terminal bud elongated with acuminate tips, appressed, reddish to brown, glabrescent, about three to six bud scales visible, the outer with a scar at tip. **Bud Content**—Lvs. with straight vernation. Flowers in the axils of the lvs. **Leaf Remnants**—Elliptical to obovate, acute to acuminate, with dark glands along midrib above, margins crenate-serrate. **Fruit Remnants**—Red to blackish pome in corymbs.

1. Twigs and buds glabrous; fruits purple-black. —*A. melanocarpa* Elliott.
1. Twigs and often part of bud pubescent; fruit purple-black to red.
   2. Buds somewhat pubescent, especially near the base of scales, the first bud scale one-fourth to one-third the length of the bud; fruit red. —**A. arbutifolia* Elliott.
   2. Buds quickly glabrous, the first bud scale often one-half the length of the bud; fruit purple to black. —**A. floribunda* Spach.

PHOTINIA Lindl.

Habit—Deciduous shrubs. **Twigs**—Slender, light brown to gray, glabrescent to puberulent. Lenticels large, orange-tan, conspicuous. Pith greenish to white, moderate to small. **Leaf Scars**—Alt., usually two-ranked, broadly V-shaped, slightly raised. Bundle scars three. No stipular scars. **Buds**—No terminal bud, laterals brown, somewhat hairy and ciliate, with four keeled and pointed bud scales visible in about two ranks. **Bud Content**—Lvs. appear entire, glabrous, with straight vernation. **Leaf Remnants**—Simple, finely serrate, pinnately veined. **Fruit Remnants**—Red pome about 8 mm. in diameter.

—**P. villosa* DC.

AMELANCHIER Med. Shadbush; Junberry

Habit—Deciduous shrubs or small trees with smooth gray bark. **Twigs**—Rather slender, reddish-brown to gray. Pith whitish, small to moderate, sometimes angled. **Leaf Scars**—Alt., two-ranked but often appearing more, spreading V-shaped. Bundle scars three. No stipular scars. **Buds**—Solitary, elongated, pointed. **Bud Content**—Lvs. with conduplicate vernation. Flower cluster when present, in center of a leaf cluster. **Leaf Remnants**—Simple, serrate, pinnately veined. **Fruit Remnants**—Small bluish-black pome in racemes.

1. Buds glabrous or only slightly pubescent or ciliate, usually over three times longer than wide.
   2. Buds usually under 10 mm. long; twigs slender, usually under 2 mm. in diameter; shrubs. —*A. oblongifolia* Roem.
   2. Buds usually over 10 mm. long; twigs usually 2 mm. or more in diameter; typically trees. —*A. canadensis* Med.
1. Buds white-woolly near ends and at edges of scales; buds never over three times longer than wide. —X *A. spicata* K. Koch.

MALUS Mill. Apple

Habit—Deciduous trees or shrubs. **Twigs**—Slender to stout, dwarf twigs commonly present, often short tomentose, sometimes ending in a spine. Lenticels usually conspicuous. Pith small to moderate, white to brownish-tan or orange, often angled in section. **Leaf Scars**—Alt., more than two-ranked, shallowly U- to V- or crescent-shaped,

somewhat raised. Bundle scars three. Stipular scars none. **Buds**—Solitary, reddish-brown, usually tomentose, at least at base, usually appressed, about three to six bud scales visible which often have two stipular tips with a scar between, especially on the terminal bud. **Bud Content**—Scales grade into lvs. which are between two stipules, the lvs. usually pubescent, vernation rather indistinct, straight, conduplicate or convolute. **Leaf Remnants**—Simple, serrate, dentate, or lobed, pinnately veined. **Fruit Remnants**—Pome with papery carpels.

1. Buds and twigs at most very sparingly pubescent, often glabrous.
   2. Pith and inner bark of older twigs orange in color; a shrub. —**M. Sieboldii* Rehd.
   2. Pith and inner bark not orange; typically trees. —**M. baccata* Borkh.
1. Buds and ends of twigs woolly pubescent.
   3. Twigs woolly only near the end; buds usually woolly near the end or at edges of scales.
      4. Lenticels conspicuous, large, pale, elongated longitudinally; cortex and pith-border not orange in color. —*X *M. micromalus* Mak.
      4. Lenticels small, not very conspicuous, little elongated; cortex and pith-border of older twigs often becoming orange colored. —**M. spectabilis* Borkh.
   3. Young twigs entirely woolly; buds whitish-woolly all over, sometimes lacking at the very base.
      5. Lenticels orange-colored; pith soon orange.
         6. Shrub with horizontally spreading branches; first bud scales usually less than one-half the bud length. —**M. Sargenti* Rehd.
         6. Typically a small tree or large shrub with ascending branches; first bud scale usually over one-half the bud length. —**M. angustifolia* Michx.
      5. Lenticels pale, not orange; pith white or rarely tan.
         7. End of twigs often ending in spines; a native tree, occasionally cult. —*M. ioensis* Brit.
         7. End of twig rarely if ever ending in a spine; cult., rarely escaped, or native but very rare.
            8. Lenticels conspicuous under hairs, very pale and elongated; common in cultivation. —**M. pumila* Mill.
            8. Lenticels not conspicuous, brown and little elongated; rarely seen in Iowa. —X *M. Soulardii* Brit.

This genus is rather uncertain and too much trust should not be placed in the species key. Fortunately only two species *M. pumila*, the common apple, and *M. ioensis*, the wild crab, are at all common.

CHAENOMELIS Lindl. Janapese Quince

Habit—Closely branched deciduous shrubs. **Twigs**—Slender, three-ridged from below each scar, thorns single at a node, the larger thorns often rough, brownish to gray twigs. Lenticels not conspicuous. Pith whitish, moderate. **Leaf Scars**—Alt., more than two-ranked, thin

crescent- or V-shaped. Bundle scars three. Stipular scars short at the ends of the leaf scars. **Buds**—No terminal bud, lateral rather small, brownish, hairy at end, three to four bud scales visible, the first one about one-half the bud length. **Bud Content**—Lvs. with stipules at sides, vernation straight. **Leaf Remnants**—Ovate, crenate-serrate, pinnately veined. Petiole winged. Stipules serrated, large. **Fruit Remnants**—Yellowish, many seeded pome.

—**C. lagenaria* Koidz.

The distinction between this and *C. japonica* Lindl., a related species, is not very great, and it is possible that some of our plants may be *C. japonica.*

CYDONIA Mill. Quince

Habit—Deciduous shrubs. **Twigs**—Moderate to slender, deep red-brown under a thick gray tomentum. Lenticels orange, conspicuous under hairs. Pith pale, moderate. **Leaf Scars**—Alt., more than two-ranked, shallowly U-shaped, somewhat raised. Bundle scars three. Stipular scars small, elongated. **Buds**—No terminal bud, laterals reddish-brown, rather hairy, appressed, with two bud scales visible, the first three-fourths or more of the bud length. **Bud Content**—A pubescent leaf between two stipules, vernation straight. **Leaf Remnants**—Simple, ovate, entire, pinnately veined, densely villous beneath. **Fruit Remnants**—Solitary, pear-shaped, villous, yellow pome.

—**C. oblonga* Mill.

PYRUS L. Pear

Habit—Deciduous trees, occasionally shrubs. Branches ascending. Bark becoming scaly-ridged. **Twigs**—Moderate, sometimes ending in a spine, glabrous. Lenticels pale. Pith pale, moderate, often rather angled. **Leaf Scars**—Alt., more than two-ranked, crescent to triangular, some raised. Bundle scars three. No stipular scars. **Buds**—Reddish-brown, nearly appressed, lateral buds rather flattened with about six bud scales visible, these glabrous or at most ciliate. **Bud Content**—Lvs. glabrescent, vernation involute. **Leaf Remnants**—Simple, elliptical to ovate, crenate-serrate margins, pinnately veined. **Fruit Remnants**—Pear-like pome, rarely remaining.

This genus includes the cultivated pears, the varieties of which are not keyed out here. The common pear, *P. communis* L. is distinguished from the Kieffer pear, X *P. Lecontei* Rehd., by its more slender twigs, its shorter buds (usually less than 5 mm. long) and its non-ciliated bud scales.

KERRIA DC. Corchorus

Habit—Deciduous shrubs. **Twigs**—Slender, rather zigzag, definitely green, three-ridged from the leaf scars, glabrous. Lenticels inconspicuous. Pith white, rather large. **Leaf Scars**—Alt., obscurely two-ranked, crescent-shaped. Bundle scars three. Stipular scars very narrow. **Buds**—Solitary, greenish to brown, about six to eight bud scales visible. **Bud Content**—Lvs. acuminate, deeply serrated, with stipules at sides, vernation seems plicate. Flowers when present solitary in the center, with five parted perianth and numerous stamens. **Leaf Remnants**—Simple, doubly serrate, pinnately veined. **Fruit Remnants**—Carpels becoming achenes. —**K. japonica* DC.

RHODOTYPUS Sieb. & Zucc.

Habit—Deciduous shrubs. **Twigs**—Slender, brown, glabrous, lenticels conspicuous. Pith pale, moderate. **Leaf Scars**—Opposite, crescent to triangular, little raised. Bundle scars three. Stipular scars narrow or a part of the stipules remaining. **Buds**—Sometimes collaterally branched, rather plump, brown to green, somewhat pubescent, about six to twelve bud scales visible. **Bud Content**—Lvs. long-acuminate, serrate, pinnately veined with straight vernation, edges seem a trifle plicate. Stipules present at sides of leaf. **Leaf Remnants**—Simple, elliptical-ovate. **Fruit Remnants**—Separating into four blackish drupes. —**R. scandens* Mak.

RUBUS L. Blackberry; Raspberry; Dewberry

Habit—Upright or trailing shrubs, ours deciduous. **Twigs**—Rather soft-wooded, usually armed with prickles or bristles, often somewhat angled. Pith brownish, large, often five-angled. **Leaf Scars**—Alt., more than two-ranked, usually not present because base of leaf petiole persists but when petiole is cut the scar is half-round, crescent- or U-shaped. Bundle scars three. Stipules remaining on petiole base. **Buds**—Moderate, often superimposed, the lower smaller, pubescent at least near the tip, three to six somewhat keeled bud scales visible. **Bud Content**—Scales grade into lvs., these are compound, lfts. with conduplicate vernation, the edges appearing plicate. **Leaf Remnants**—Edges of lfts. serrate. **Fruit Remnants**—A syncarp of drupelets, sometimes present as dried, partially developed structures, or in the raspberries the drupelets fall leaving a naked conical receptacle.

1. Trailing or mostly trailing—the dewberries belong here The native one is *R. flagellaris* Willd. found in the eastern part of Iowa on sandy soil. A variety of this species is cultivated, but very rarely.

1. Erect, open or recurved branches.
   3. Branches conspicuously glaucous.
      4. Stems with numerous stiff bristles, hooked prickles present or absent. —*R. idaeus aculeatissimus* Reg. & Tiling.
      4. Stems with stout, hooked prickles but no bristles. —*R. occidentalis* L.
   3. Branches not glaucous. —*R. allegheniensis* Porter.

The genus Rubus is in a very unsatisfactory taxonomic condition. *R. flagellaris* is here considered as the same as *R. villosus* of Gray's Manual, seventh edition. *R. triflorus* Richards. and *R. cuneifolius* Pursh. have been reported from the eastern part of the state.

POTENTILLA L. Cinquefoil; Five-finger

Habit—Low deciduous shrubs. **Twigs**—Rather slender, gray to tan, short hairy, the older twigs with bark exfoliating. Lenticels not noticeable. Pith brown, rather small, sometimes spongy. **Leaf Scars**—Alt., usually more than two-ranked, round on a raised base. Bundle scars one. Stipules persist at sides of leaf scar. **Buds**—Solitary, moderate, brownish to gray, hairy, especially at end, appressed, with three to six striated, rather two-ranked bud scales visible, the outer often toothed at the apex. **Bud Content**—Lvs. compound, white silky-hairy, vernation of lfts. not distinct but appearing conduplicate. Stipules present at sides of leaf. **Leaf Remnants**—Pinnately compound, of three to seven lfts., the margins entire, pubescent. **Fruit Remnants**—Achenes on a conical receptacle. —*P. fruticosa* L.

A very low-growing species *P. tridentata* Ait. has been found very local in northeastern Iowa, but it is not included here because it is hardly woody, except at the very base.

ROSA L. Rose

Habit—Deciduous shrubs, with upright, trailing or climbing stems. **Twigs**—Moderate, not ridged, usually armed with prickles and often with bristles, usually reddish to green, glabrous. Pith pale, becoming in some cases brown, large. **Leaf Scars**—Alt., more than two-ranked, little raised, narrowly U to linear in shape. Bundle scars three. Stipular scars none. **Buds**—Rather small, solitary, seldom pubescent, with two to five bud scales visible. **Bud Content**—Lvs. with flat base, two stipules at sides, pinnately compound in our species, lfts., serrate with conduplicate vernation. **Leaf Remnants**—Compound, stipules present (in ours). **Fruit Remnants**—A hip becoming fleshy and enclosing bony achenes.

The species of this genus are very variable and very easily hybrid-

ized. This results in taxonomic confusion, especially in the cultivated forms. Some of the native species can be recognized in winter condition, but it is thought best not to include here a species key.

PRUNUS L. Plums; Peaches; Cherries; Apricots

Habit—Deciduous trees or shrubs. **Twigs**—Slender to moderate, bark of twig often bitter-tasting. Lenticles often prominent. Pith whitish to tan, round or somewhat angled. **Leaf Scars**—Alt., more than two-ranked, half-round or oval, definitely raised. Bundle scars three, sometimes indistinct. Stipular scars at top side of leaf scar or the stipules wholly or partly remaining. **Buds**—Terminal bud present or absent, lateral buds solitary or collaterally multiple, often in threes, the side buds being thicker, about three to ten bud scales visible, these in more than two ranks and often with teeth or scars at the tip of the scale. **Bud Content**—Lvs. simple, pinnately veined, the vernation various. Flowers with five sepals, five petals, many stamens and one style. **Leaf Remnants**—Serrated; raised glands often present at base of blade or top of the petiole. **Fruit Remnants**—Drupe.

1. Terminal bud lacking.
    2. Twigs short tomentose; buds pubescent; never tree-like. —**P. gracilis* Engelm. & Gr.
    2. Twigs glabrous; buds at most ciliate; often trees.
        3. Cultivated fruit trees; lateral buds commonly multiple.
            4. Buds dark brown, scales ciliate, the flower buds containing only one flower. —**P. Armeniaca* L.
            4. Buds light brown to gray green, scales little if at all ciliate, usually two or more flowers in the bud. —**P. domestica* L.
        3. Not cultivated for fruit, and seldom seen in cultivation; buds commonly solitary.
            5. Native, rather common; lenticels inconspicuous. —*P. americana* Marsh.
            5. Not native, and rarely cultivated; lenticels conspicuous. —**P. sibirica* L
1. Terminal bud present.
    6. Never tree-like.
        7. Twigs tomentose to finely puberulent.
            8. Twigs heavily tomentose; stipules if present setaceous —**P. tomentosa* Thunb.
            8. Twigs puberulent; stipules if present fimbriate-serrate like a comb. —**P. triloba plena* Dipp.
        7. Twigs glabrous.
            8. Twigs two-ridged below each scar; lenticels conspicuous; buds blunt; native but rare in Iowa —*P. pumila* L.
            8. Twigs not ridged; lenticels not conspicuous; buds somewhat pointed; not native.

9. Over five bud scales visible on side lateral buds, which are short, ovoid; somewhat prostrate in habit. —**P. Besseyi* Bailey
9. Bud scales five or less visible on the side lateral buds which are long-ovoid; upright in habit. —**P. glandulosa* Thunb.
6. Typically trees.
10. Lateral buds tending to crowd out near the end of the twig, often extending out farther than the terminal bud. —*P. pennsylvanica* L.
10. Lateral buds not clustered near the end of twig.
11. Twigs densely short hairy. —**P. mahaleb* L.
11. Twigs glabrous or nearly so.
12. Twigs green or reddish, often with both colors on opposite sides of the twig; buds usually woolly. —**P. Persica* Batsch.
12. Twigs gray to reddish-brown; buds glabrous.
13. Buds usually over 6 mm. long, appressed, bud scales light brown with a broad marginal band of gray.
14. Twigs grayish brown; lenticels of young twig strongly elongated longitudinally; native. —*P. virginiana* L.
14. Twigs reddish-brown to light-brown; lenticels on young twig not or only slightly elongated; not native here. —**P. Padus* L.
13. Buds under 6 mm. long, not appressed, bud scales reddish-brown, marginal band if present very narrow.
15. Twigs light-brown, lenticels on the second or third year's growth longitudinally elongated. —**P. avium* L.
15. Twigs reddish-brown to gray, lenticels on second or third year's growth somewhat transversely elongated.
16. Young twigs slender, seldom over 2 mm. in diameter, bark of trunk in scales or plates; native. —*P. serotina* Ehrh.
16. Young twigs moderate, usually over 2 mm. in diameter; bark of trunk not in scales or plates; a cultivated fruit tree. —**P. Cerasus* L.

The species of this genus are rather difficult in winter and too much reliance should not be placed on any key. Many of the species listed in this key are very rare and will seldom be encountered. In addition to the list above two other species have been reported as being very rarely found native in Iowa, *P. nigra* Ait. and *P. hortulana* Bailey. An ornamental shrub or small tree with reddish-purple leaves is appearing in cultivation. It seems to be *P. cerasifera Pissartii* Bailey., or the hybrid X *P. cistena* N. E. Hansen.

PRINSEPIA Royle.

Habit—Deciduous shrubs. **Twigs**—Slender, rather zigzag, grayish to gray-brown, spiny with spines super-axillary, above the buds. Lenticels, dark, not very conspicuous. Pith pale, sometimes yellowish, moderate to large, finely chambered. **Leaf Scars**—Alt., more than two-ranked, half round to oval, some raised. Bundle scar one, indistinct. Stipules present at top of scar and covering part of bud.

Buds—Solitary, no scales distinct, the bud and stipule inside woolly hairy. **Bud Content**—Lvs. lanceolate, entire, glabrous, purple-tipped with two narrow stipules at sides, the vernation convolute. Flowers and lvs. in the same bud, flowers with five sepals, many stamens and one style. **Leaf Remnants**—Simple, pinnately veined, ovate-lanceolate. **Fruit Remnants**—Purple drupe 1.5 cm. long.

—**P. sinensis* Oliver.

Family LEGUMINOSAE

CERCIS L. Redbud; Judas-tree

Habit—Small, deciduous trees, bark becoming somewhat ridged and scaly. **Twigs**—Slender, rather zigzag, dark reddish-brown, glabrous. Lenticels numerous, small but conspicuous. Pith white to pinkish-streaked, moderate. **Leaf Scars**—Alt., two-ranked, rather triangular, fringed on top. Bundle scars three. Stipular scars none. **Buds**—Often superimposed, the flower buds stalked, brittle, dark brown, several ciliate often keeled bud scales visible. **Bud Content**—Lvs. entire, simple, glabrous with stipules present, vernation conduplicate, the midrib large. Flower buds containing several reddish, irregular flowers. **Leaf Remnants**—Broadly ovate, glabrous, palmately veined. **Fruit Remnants**—Often present, flat pods 6 to 8 cm. long-winged on one suture. —*C. canadensis* L.

GLEDITSIA L. Honey-Locust

Habit—Deciduous trees with bark gray to darker, becoming roughened in broad ridges. **Twigs**—Slender, rather zigzag, shiny, thorns usually present at some of the nodes, the spines often branched, with reddish pith. Lenticels small. Pith rather large, whitish. **Leaf Scars**—Alt., more than two-ranked, rather V-shaped. Bundle scars three, not conspicuous. Stipular scars not noticeable. **Buds**—No terminal bud, lateral buds superimposed, wholly or partially concealed. **Bud Content**—Lvs. small but compound. **Leaf Remnants**—Pinnately or bipinnately compound, indistinctly crenate. **Fruit Remnants**—Reddish-brown twisted pod 30 to 45 cm. long. —*G. triacanthos* L.

GYMNOCLADUS L. Kentucky Coffee-tree

Habit—Deciduous trees, bark roughened with recurved scale-like ridges. **Twigs**—Very stout, often contorted, with a gray skin. Lenticles large, paler, conspicuous. Pith large, salmon to reddish-brown. **Leaf Scars**—Alt., more than two-ranked, irregularly heart-shaped,

about parallel to twig. Bundle scars three to five, often individually U-shaped. Stipular scars lacking or extremely minute. **Buds**—Superimposed, partly concealed in a silky patch, scales indistinct. **Bud Content**—Lvs. small, compound. **Leaf Remnants**—Bipinnately compound, the lfts. entire. **Fruit Remnants**—Broad, oblong, flat pod, 15 to 25 cm. long, often remaining. —*G. dioica* K. Koch.

CLADRASTIS Raf. Yellow-wood

Habit—Rather small, deciduous trees, bark smooth and gray. **Twigs**—Rather slender and zigzag, reddish-brown beneath gray skin. Lenticels paler. Pith whitish, rather large. **Leaf Scars**—Alt., two or more than two-ranked, horseshoe-shaped, almost encircling the bud. Bundle scars usually seven, raised. Stipular scars none. **Buds**—Generally two to four superimposed, closely grouped and appearing as one, gray tan to yellow, very hairy and no definite bud scales. **Bud Content**—Inner structure very hairy and no detail apparent. **Leaf Remnants**—Pinnately compound of seven to nine entire lfts. **Fruit Remnants**—Thin pod 7 to 8 cm. long. —**C. lutea* K. Koch.

SOPHORA L. Japan Pagoda-tree

Habit—Deciduous trees or rarely shrubby, bark furrowed. **Twigs**—Moderate, swollen at nodes, greenish, sparingly pubescent. Lenticels pale, large, few conspicuous. Pith pale, rather small, often angled. **Leaf Scars**—Alt., more than two-ranked, raised, becoming U- to horseshoe-shaped when the buds break through the top. Bundle scars three. Stipular scars or remnants very minute. **Buds**—Small, almost concealed, very hairy, massed, superimposed, indistinctly scaly. **Bud Content**—Too small to make out. **Leaf Remnants**—Pinnately compound, with seven to seventeen entire lfts. **Fruit Remnants**—A terete pod 5 to 8 cm. long. —**S. japonica* L.

GENISTA L.

Habit—Deciduous or half evergreen shrubs. **Twigs**—Greenish, either winged or ridged. Pith white. **Leaf Scars**—Half-oval, when present. Bundle scar one. Stipules sometimes present. **Buds**—About two bud scales visible. **Leaf Remnants**—Entire, rather villous, pinnately veined. **Fruit Remnants**—A pod.

1. Twigs with two broad green wings; stems rather procumbent. —**G. sagittalis* L.
1. Twigs ridged but not winged; stems not procumbent. —**G. tinctoria* L.

CYTISUS L. Broom

Habit—Low, sometimes prostrate, deciduous shrubs. **Twigs**—Slender to moderate, often two-ridged from the leaf scar, greenish to gray, pubescent. Lenticels not conspicuous. Pith whitish, small. **Leaf Scars**—Alt., more than two-ranked, oval to half-round, small, raised, forming a shelf on which the bud rests. Bundle scar one, often indistinct. Stipular scars absent or very small. **Buds**—Solitary, small, seldom over 3 mm. in length, pubescent, ciliate, about four to eight bud scales visible which are often indistinct. **Bud Content**—Too small to make out detail. **Leaf Remnants**—Often present, simple or three foliate, entire, pubescent below. **Fruit Remnants**—A pod, long-villous, 2 to 3 cm. long.

1. Small, prostrate shrub seldom over 25 cm. high; buds very sparingly pubescent; lvs. simple. —**C. decumbens* Spach.
1. Rather upright, larger, over 25 cm. high; buds pubescent, especially near the ends; lvs. three-foliolate.
   2. Twigs ridged beneath leaf scars. —**C. nigricans* L.
   2. Twigs not at all ridged. —**C. supinus* L.

AMORPHA L. Lead-plant; False-Indigo

Habit—Deciduous shrubs. **Twigs**—Rather slender, longitudinally ridged, light-brown to gray. Lenticels inconspicuous. Pith whitish or on older twigs becoming brownish, moderate. **Leaf Scars**—Alt., more than two-ranked, triangular to crescent-shaped, rather raised. Bundle scars three. Stipular scars small and very inconspicuous, at upper angles of leaf scar. **Buds**—Solitary or superimposed, gray to brown, hairy, with two to six bud scales visible. **Bud Content**—Lvs. small, pinnately compound. **Leaf Remnants**—Odd-pinnately compound. **Fruit Remnants**—Often present as a small, short, one-seeded pod in dense panicles or spikes.

1. Buds superimposed; moderately tall shrubs. —*A. fruticosa* L.
1. Buds solitary, low shrubs.
   2. Twigs white woolly; pod villous. —*A. canescens* Nutt.
   2. Twigs glabrate; pods glabrous. —*A. microphylla* Pursh

WISTERIA Nutt. Wistaria

Habit—Deciduous, twiners. **Twigs**—No tendrils, three-angled from below the leaf scars, light to reddish-brown, often retrorsely hairy. Lenticels pale, not very conspicuous. Pith whitish, fairly large. **Leaf Scars**—Alt., two- or more than two-ranked, half-round, decidedly raised. Bundle scar one, large, in the center of the leaf scar and sometimes compound. Stipular scars lacking but on lower sides of the leaf scar are two wart-like "horns." **Buds**—Solitary, brownish,

pubescent at tip, short conical with about two scales visible, the first nearly covering the bud. **Bud Content**—Pinnately compound, vernation of lfts. conduplicate. **Leaf Remnants**—About nine entire lfts. **Fruit Remnants**—A pod, often large, up to 12 cm. long.
—**W. macrostachya* Nutt.

Although the above species is the only one located in the present work others may be expected in cultivation. *W. frutescens* DC. and *W. sinensis* Sweet., should be found in this region.

ROBINIA L. Locust

Habit—Deciduous trees or shrubs. **Twigs**—Moderate, often zigzag, bristles or stipular spines often present. Lenticels not very conspicuous. Pith whitish to light-brown, moderate, often somewhat angled. Wood rather yellowish. **Leaf Scars**—Alt., more than two-ranked, broadly triangular or three-lobed but usually split from beneath by the developing buds, raised. Bundle scars three. Stipular scars if present spinescent. **Buds**—No terminal bud, the laterals usually partly concealed, superimposed and hairy, the scales indistinct. **Bud Content**—Hairy, the parts indistinct. **Leaf Remnants**—Pinnately compound, with odd numbers of entire lfts. **Fruit Remnants**—Flat pod.

1. Twigs beset with numerous long bristles; a shrub. —**R. hispida* L.
1. Twigs without bristles; usually trees. —*R. pseudoacacia* L.

COLUTEA L. Bladder Senna

Habit—Deciduous shrubs. **Twigs**—Moderate, angled from leaf scars, greenish to gray. Lenticels brown, conspicuous. Pith white to greenish, moderate. **Leaf Scars**—Alt., more than two-ranked, half-oval. Bundle scars three or the middle one three-parted. Stipules persistent. **Buds**—Commonly superimposed, the upper usually developing into a branch, small, with two to four scales visible. **Bud Content**—Pinnately compound, whitish-brown woolly lvs. lying between stipules. **Leaf Remnants**—About nine to thirteen entire lfts. **Fruit Remnants**—Inflated pod, 6 to 8 cm. long. —**C. arborescens* L.

CARAGANA Lam.

Habit—Deciduous shrubs or rarely small trees. **Twigs**—Rather slender, usually three-ridged from the leaf scar, spines often present as stipule remains or the end of the old leaf rachis. Pith whitish or greenish white, often angular in section. **Leaf Scars**—Alt., two-ranked or more than two-ranked, oval or half round, raised definitely but often absent due to the persistent leaf rachis. Bundle scar one. Stipules present. **Buds**—Solitary, with three to five visible bud scales,

some of these often with a scar at the tip and stipular-like appendages. **Bud Content**—Compound leaf with stipules, vernation of lfts. appearing conduplicate. **Leaf Remnants**—Pinnately even-compound, the lfts. entire, the leaf rachis weakly spinescent at ends. **Fruit Remnants**—Pod.

1. Leaf rachis soon falling, at least on the older wood.
   2. Stipules spinescent; lvs. if present with eight to eighteen lfts.
      3. Stipular spines about 4 mm. or less in length; young twigs only faintly ridged; low shrub, under 3 m. high. —**C. microphylla* Lam.
      3. Stipular spines about 5 mm. long; twigs all three ridged; often over 3 m. tall. —**C. arborescens* Lam.
   2. Stipules present but not spinescent; lvs. if present with four lfts. —**C. frutex* K. Koch.
1. Leaf rachis remaining as a weak spine.
   4. The two pairs of lft. scars crowded close together on the leaf rachis.
      5. Lft. scars near end of leaf rachis —**C. grandiflora* DC.
      5. Lft. scars near middle or base of leaf rachis. —**C. aurantiaca* Koehne.
   4. The two pairs of lft scars separated on the leaf rachis, the first pair near the middle and the second near the end. —**C. chamlagu* Lam.

Family RUTACEAE

ZANTHOXYLUM L. Prickly Ash; Toothache-tree

Habit—Deciduous shrubs or rarely small trees. **Twigs**—Moderate to stout, gray, usually two prickles at a node. Lenticels not conspicuous. Pith white, large. Wood rather aromatic. **Leaf Scars**—Alt., more than two-ranked, broadly triangular, sometimes torn at top, slightly raised. Bundle scars three, each a circle or C-shaped. Stipular scars lacking. **Buds**—Moderate, superimposed but often indistinctly so, globose, brownish-red, pubescent, indistinctly scaly, terminal bud larger. **Bud Content**—Reddish-woolly within. **Leaf Remnants**—Pinnately compound, of five to eleven crenate lfts. **Fruit Remnants**—Dehiscent follicles, the seeds shiny black.

—*Z. americanum* Mill.

PTELEA L. Hop-tree

Habit—Deciduous shrubs, rarely small trees. **Twigs**—Slender to moderate, brownish, glabrous. Lenticels brown, large, numerous and conspicuous. Pith large and white. **Leaf Scars**—Alt., more than two-ranked, horseshoe-shaped when torn in center by the developing buds, raised. Bundle scars three. Stipular scars none. **Buds**—Terminal bud absent, laterals small and appear partly concealed, densely tan or buff hairy, no distinct bud scales, probably superimposed. **Bud**

Content—Hairy and indistinct. **Leaf Remnants**—Palmately compound, of three elliptical to obovate lfts. **Fruit Remnants**—A winged hop-like samara. —*P. trifoliata* L.

PHELLODENDRON Rupr. Cork-tree

Habit—Small, deciduous trees, bark light gray, usually corky and deeply fissured. **Twigs**—Stout, somewhat flattened at nodes, orange-brown. Lenticels elongated and conspicuous. Pith pale but often becoming brownish, rather large. Bark of twig thick, outer part green, the inner part bright yellow. Wood rays prominent. **Leaf Scars**—Opposite, large, horseshoe-shaped, raised. Bundle scars in three groups, the middle one often compound. Stipular scars none. **Buds**—Solitary, flattened from end and appearing partly concealed, reddish-brown, hairy, with about two to four rather indistinct bud scales visible. **Bud Content**—Lvs. compound, pubescent, vernation of lfts. seems revolute. **Leaf Remnants**—About eleven lfts. **Fruit Remnants**—Blackish drupe, about 1 cm. in diameter. —**P. amurense* Rupr.

Family SIMARUBACEAE

AILANTHUS Desf. Tree of Heaven

Habit—Deciduous, rapidly growing trees, with rather smooth bark. **Twigs**—Very stout, tan to reddish, glabrous. Lenticels raised, reddish. Pith light brown, large. **Leaf Scars**—Alt., more than two-ranked, shield-shaped. Bundle scars scattered in a row near the edge, numerous. Stipular scars none. **Buds**—No terminal bud, laterals solitary, reddish-brown, partly concealed, about two to four bud scales visible. **Bud Content**—Lvs. seem pinnately compound. **Leaf Remnants**—Lfts. entire except at very base, green above, lighter below. **Fruit Remnants**—Winged, 3 to 4 cm. long borne in panicles. —**A. altissima* Swingle.

Family BUXACEAE

BUXUS L. Box

Habit—Evergreen, usually shrubs. **Twigs**—Rather slender, quadrangular with two ridges from each decurrent leaf, greenish to gray, pubescent, especially on the side above the leaf. Lenticels inconspicuous. Pith green, small, often angled in section. **Leaf Scars**—Opposite, half round. Bundle scar one. Stipular scars none. **Buds**—Small, the flower buds clustered, slightly pubescent, gray, usually about four keeled scales visible. **Bud Content**—Scales grade into lvs., ver-

nation straight. Flowers with rather definite parts. **Leaf Remnants**—Entire, oblong to elliptical, somewhat revolute. **Fruit Remnants**—Capsule, three horned, about 8 mm. long. —**B. sempervirens* L.

Family ANACARDIACEAE

COTINUS Adans. Smoke-tree

Habit—Deciduous, large shrubs or small trees. **Twigs**—Moderate to stout, glabrous. Lenticels definite. Pith moderate, brown. Older wood rather yellowish, especially the heartwood, and exhuding a gummy aromatic sap. **Leaf Scars**—Alt., more than two-ranked, half round to rather three lobed. Bundle scars usually three, sometimes more, often rather C-shaped. Stipular scars none. **Buds**—Terminal present, glabrous, about four bud scales visible. **Bud Content**—Inner scales ciliate, grading into the ovate, entire, pinnately veined lvs., vernation straight. Flowers in a cone-shaped cluster inside the lvs. **Leaf Remnants**—Glabrous, with eight to ten pairs of veins. **Fruit Remnants**—A drupe 3 to 4 mm. in diameter borne on a very long hairy panicle.

1. Leaf scars higher or at least as high as wide, often slightly three-lobed, definitely concave at the top; twigs light brown to tan. —**C. americanus* Nutt.
1. Leaf scars wider than high, not three-lobed, usually but slightly concave at top; twigs brownish-red to gray. —**C. coggygria* Scop.

This genus has rather well marked winter characters but the two species are hard to distinguish without the lvs.

RHUS L. Sumach

Habit—Deciduous vines, shrubs, or rarely small trees. **Twigs**—Slender to stout, often showing milky, sticky sap. Pith pale to yellow-brown, usually large. **Leaf Scars**—Alt., more than two-ranked, C-, horseshoe-, round-, or crescent-shaped. Bundle scars numerous, scattered, or in a U-shaped line, often broken into five to nine. Stipular scars none. **Buds**—Small to moderate, often partly concealed, indistinctly scaly, very hairy. **Bud Content**—Lvs. compound, very woolly. **Leaf Remnants**—Pinnately compound or of three lfts. **Fruit Remnants**—Drupes in panicles.

1. Leaf scars C- or horseshoe-shaped, nearly encircling the bud.
    2. Twigs glabrous. —*R. glabra* L.
    2. Twigs velvety hairy. —*R. typhina* L.
1. Leaf scars various, but not C- or horseshoe-shaped.
    3. Leaf scars round-elevated, almost or completely covering the bud.
        4. Twigs somewhat ridged from below the leaf scars, sparsely short-hairy toward the end; fragrant scented; staminate catkin 8 mm. or more long. —*R. canadensis* Marsh.

4. Twigs not ridged, short pubescent, especially near the ends; ill scented; staminate catkin less than 6 mm. long. —**R. trilobata* Nutt.

3. Leaf scars not round-elevated.

5. Buds somewhat stalked, the end bud over 4 mm. long; lenticels not conspicuous; often climbing by aerial roots. —*R. Toxicodendron* L.

5. Buds sessile or partly concealed, under 4 mm. long; lenticels very conspicuous; never climbing. —? **R. copallina* L.

This genus is very diverse in its winter characters and contains the poison ivy and poison sumach which affect susceptible people even in winter. The poison sumach, *R. vernix* L., apparently has no authenticated record in Iowa, although it is found in western Illinois, Minnesota, and Missouri, according to McNair(40).

Family AQUIFOLIACEAE

Ilex L. Holly

Habit—Evergreen or deciduous shrubs, rarely trees. **Twigs**—Small to moderate. Lenticels not conspicuous. Pith pale, small to moderate, often angled. **Leaf Scars**—Alt., more than two-ranked, half round. Bundle scar one, often indistinct. Stipules usually present or leaving a scar. **Buds**—Small, with three to four rather indistinct bud scales visible. **Bud Content**—Small leaf between stipules. **Leaf Remnants**—Simple, pinnately veined. **Fruit Remnants**—Globose berry-like drupe.

1. Lvs. evergreen

2. Lvs. with spiny teeth, over 3 cm. long. —**I. opaca* Ait.

2. Lvs. crenate near tip, never spiny, less than 2 cm long. —* *I. crenata* Thunb.

1. Lvs. deciduous. —*I. verticillata* Gray.

Family CELASTRACEAE

Evonymus L. Spindle-tree; Burning-bush

Habit—Usually deciduous shrubs, vines, or rarely small trees. **Twigs**—Greenish to rose-colored, four-ridged from below leaf scar, sometimes winged. Pith white to green, rather four-angled, often spongy or excavated. **Leaf Scars**—Opposite, half round, little raised. Bundle scar one, as a curved line. Stipular scars none or very minute. **Buds**—Greenish to brownish-red, glabrous, with six to ten opposite and four-ranked bud scales visible. **Bud Content**—Scales grade into lvs. which are simple, glabrous, and pinnately veined, vernation straight to involute. **Leaf Remnants**—Elliptical to ovate. **Fruit Remnants**—Capsule four-lobed and four-parted, dehiscent to expose a fleshy orange aril.

1. Stems climbing; evergreen. —**E. radicans* Sieb.

1. Stems not climbing; deciduous.

2. Twigs corky winged; ten or more bud scales visible. —**E. alata* Reg.
2. Twigs not corky winged; less than ten bud scales visible.
   3. Bud scales appressed, margins dry, and reddish-brown; not native. —**E. europaea* L.
   3. Bud scales loose, margins not dry nor reddish-brown; native. —*E. atropurpurea* Jacq.

The corky wings on the twigs of *E. alata* were described in 1888 by Gregory (24).

CELASTRUS L. Staff-tree; Bittersweet

Habit—Deciduous twiners. **Twigs**—Rather slender, brown to gray, glabrous. Lenticels not very conspicuous. Pith white, rather large. **Leaf Scars**—Alt., more than two-ranked, half round. Bundle scar one. Stipular scars as a tuft of hairs. **Buds**—No terminal bud, laterals about 2 mm. long, light brown, glabrous, about five to eight bud scales visible, the outer somewhat keeled. **Bud Content**—Inner scales tan only near tip, about five to eight present. Lvs. entire, glabrous, pinnately veined with straight vernation. **Leaf Remnants**—Ovate to oblong-ovate, acuminate, cuneate, the margins crenate-serrate. **Fruit Remnants**—Often present as orange-yellow, dehiscent capsules exposing a scarlet aril.

1. Fruit in axillary cymes; twigs slightly two-ridged from below the leaf scars; not native. —**C. articulata* Thunb.
1. Fruit in terminal panicles; twigs not ridged; native but often in cult. —*C. scandens* L.

PACHISTIMA Raf.

Habit—Low spreading evergreen shrubs. **Twigs**—Slender, four-ridged reddish-green to brown, slightly pubescent. Lenticels not conspicuous. Pith pale to brownish, minute. **Leaf Scars**—Opposite, half round, slightly raised. Bundle scar one, indistinct. Stipular scars none. **Buds**—Very small, with two to four green scales visible. **Bud Content**—Lvs. entire, glabrous, vernation straight. **Leaf Remnants**—Elliptical, serrated near the end. **Fruit Remnants**—Leathery two-valved capsule. —**P. myrsinites* Raf.

TRIPTERYGIUM Hook.

Habit—Deciduous shrubs. **Twigs**—Moderate, angled to winged, three from a scar, the middle one smaller, very warty, zigzag, brown. Pith pale, moderate, sometimes with firmer cross plates. **Leaf Scars**—Alt., more than two-ranked, half round, raised. Bundle scar one, rather U-shaped. Stipular scars none. **Buds**—Moderate, solitary, brown, glabrescent, divergent at about sixty degree angle from the twig, about

four keeled bud scales visible. **Bud Content**—Scales grade into glabrous lvs. which have small narrow stipules at sides, the vernation straight. **Leaf Remnants**—Large, ovate to broad elliptical, crenate-serrate. **Fruit Remnants**—Nutlet, three-winged and one-seeded.
—**T. Regelii* Sprague & Tak.

Family STAPHYLEACEAE

STAPHYLEA L. Bladdernut

Habit—Deciduous shrubs or small trees. **Twigs**—Moderate, greenish, thickly spotted with dark red or gray, glabrous, older twigs with light streaks. Lenticels inconspicuous. Pith white, large. **Leaf Scars**—Opposite, half round to broadly crescent-shaped, somewhat raised. Bundle scars three or sometimes up to seven. Stipular scars half round, not connected to the leaf scar. **Buds**—Solitary, reddish-brown, glabrous, ovoid, end bud lacking, about four bud scales visible. **Bud Content**—Lvs. ternately compound, vernation of lfts. involute. Flower cluster in center of lvs., five sepals, five petals, five stamens and three styles. **Leaf Remnants**—Lfts. finely serrate, the lateral two sessile. **Fruit Remnants**—Inflated capsule. —*S. trifolia* L.

Family ACERACEAE

ACER L. Maple

Habit—Deciduous, usually trees. **Twigs**—Usually moderate, varying from brown, red, to gray. Pith whitish to brown. **Leaf Scars**—Opposite, narrow U- or V-shaped. Bundle scars three. Stipular scars none but opposite leaf scars meeting or connected by a transverse ridge. **Buds**—Solitary or sometimes collaterally multiple, sometimes stalked, terminal bud present or absent in one species, often replaced, however, by a fruit remnant, bud scales four-ranked and opposite. **Bud Content**—Young lvs. compound or somewhat lobed. **Leaf Remnants**—Compound or palmately veined and lobed. **Fruit Remnants**—Samara with two winged nutlets.

1. End bud always lacking. —**A. palmatum* Thunb.
1. End bud present on some of twigs.
  2. Lateral buds stalked, usually only two bud scales visible; pith becoming orange to brown.
    3. Older twigs and young branches conspicuously white-streaked; twigs moderate, glabrous. —**A. pennsylvanicum* L.
    3. Older twigs at most faintly striped; twigs slender, appressed hairy. —*A. spicatum* Lam.

2. Lateral buds not stalked; more than two bud scales visible; pith usually whitish.
   4. Buds densely woolly; twigs commonly covered with a glaucous bloom; lvs. in bud pinnately compound. —*A. Negundo* L.
   4. Buds not densely woolly, although sometimes pubescent; twigs not glaucous; lvs. in bud lobed but not compound.
      5. Edges of opposite leaf scars meeting in a slight projection; buds often milky when cut; two pairs of inner bud scales brownish silky hairy. —**A. platanoides* L.
      5. Edges of opposite scars not meeting but connected by a ridge; buds never milky; none of inner bud scales brown-hairy.
         6. Terminal bud with more than four pairs of bud scales visible; buds conical and acute.
            7. Buds glabrous or somewhat pubescent at apex; bark of trunk dark gray. —*A. saccharum* Marsh.
            7. Buds short-pubescent over entire surface; bark dark, blackish. —*A. nigrum* Michx.
         6. Terminal bud never with more than four pairs of bud scales visible; buds ovoid and blunt.
            8. Twigs brown to straw-colored; flower buds not clustered; six or less than six bud scales visible.
               9. Twigs and bud short-tomentose; lvs. in bud with edges plicate. —**A. campestre* L.
               9. Twigs glabrous; buds at most ciliate; lvs. in the bud with edges only slightly if at all plicate. —**A ginnala* Maxim.
            8. Twigs bright reddish or brownish-red; flower buds in clusters; usually six to eight bud scales visible.
               10. Bark of large trunks becoming flaky; twigs with a rank odor when bruised; bud scales somewhat pointed at apex. —*A. saccharinum* L.
               10. Bark not becoming flaky; no rank odor when twigs are bruised; bud scales rounded at apex. —*A. rubrum* L.

A. nigrum is sometimes considered as a variety of *A. saccharum* and does resemble it closely. Rehder (46) following Bailey (2) considers them specifically distinct.

Family HIPPOCASTANACEAE

AESCULUS L. Horse-chestnut; Buckeye

Habit—Deciduous round topped trees, bark dark, broken into scaly plates. **Twigs**—Stout, brown to gray, glabrous or nearly so. Lenticels rather conspicuous. Pith whitish, moderate to large. **Leaf Scars**—Opposite, shield-shaped, triangular to round. Bundle scars usually six or seven, often in three groups. Stipular scars none. **Buds**—Solitary, very large, especially the terminal, often resinous, brownish, scales in four ranks, the outer pair woody and keeled. **Bud Content**—Lvs. compound, densely woolly, vernation of lfts. conduplicate, the

edges slightly plicate. Flower cluster in center of lvs. and very woolly. **Leaf Remnants**—Lfts. five to seven, palmate. **Fruit Remnants**—Dehiscent, one seeded, usually spiny, often remaining.

1. Buds more or less gummy or resinous, the inner scales not rosy red at base; terminal bud often over 2.5 cm. long; fruit with spines.
   2. Buds heavily resinous; fruit very spiny; commonly planted. —**A. Hippocastanum* L.
   2. Buds becoming rather dry and thinly resinous; fruit with a few, weak spines; very uncommon. —*X *A. carnea* Hayne.
1. Buds not at all resinous, the inner scales rosy red at base; terminal bud less than 2.5 cm. long; fruit without spines. —*A. glabra* Willd.

Two other species of Aesculus, *A. octandra* Marsh. and *A. arguta* Buckl., the latter often considered merely as a shrubby form of *A. glabra,* have been reported in Iowa but are rarely found.

Family SAPINDACEAE

XANTHOCERAS Bge.

Habit—Deciduous shrubs or small trees. **Twigs**—Rather stout, buff to tan, the older twigs gray, glabrescent. Lenticels fairly conspicuous. Pith light brownish, rather large, often irregularly round. **Leaf Scars**—Alt., more than two-ranked, crescent to half elliptical in shape, somewhat raised. Bundle scars three. Stipular scars none. **Buds**—Solitary, reddish-brown to brown, slightly pubescent, laterals appressed with about four to six bud scales visible, terminal bud with filiform tips. **Bud Content**—Scales whitish hairy on inside, and by lobing on sides grade into the pinnately compound leaf, which has a large rachis and very small lfts. **Leaf Remnants**—About nine to seventeen lfts. **Fruit Remnants**—Loculicidal three-valved capsule, the seeds dark brown. —**X. sorbifolia* Bge.

Family RHAMNACEAE

RHAMNUS L. Buckthorn

Habit—Deciduous shrubs or small trees. **Twigs**—Slender to moderate, usually gray or brownish. Pith whitish, small to moderate, often rather angled. **Leaf Scars**—Opposite or alt. and more than two-ranked. Bundle scars three or fused as a line. Stipular scars small or part of stipule remaining. **Buds**—Solitary, naked or scaly, brown to gray, appressed or almost so. **Bud Content**—Lvs. simple, pinnately veined with stipules at sides, vernation various, the opposite-leaved species involute. **Leaf Remnants**—Margins entire or serrate. **Fruit Remnants**—Blackish drupe with nutlets.

1. Leaf scars opposite, rarely obscurely so; end of twig often forming a spine.
   2 Spines at end of twigs much longer than the last pair of lateral buds. —**R. japonica* Maxim.
   2. Spines shorter or very slightly longer than the last lateral buds.
      3. Buds and twigs very dark brown under a gray skin; bud scales conspicuously gray or tan at margins.
         4. Buds glabrous; twigs glabrous or slightly downy pubescent. —**R. cathartica* L.
         4. Buds and young twigs definitely scurfy pubescent. —**R. saxatilis* Jacq.
      3. Buds and twigs light brown; bud scales uniform in color. —**R. davurica* Pall.
1. Leaf scars alt.; twigs spineless.
   5. Buds naked, no definite bud scales, very tomentose; end bud present. —**R. Frangula* L.
   5. Buds with evident bud scales, at most puberulent to ciliate; end bud lacking.
      6. Twigs gray, scurfy pubescent near the end; tall shrubs or small trees. —*R. lanceolata* Pursh.
      6. Twigs brownish to gray-brown, glabrous or very short hairy; low shrubs; rare. —*R. alnifolia* L'Herit.

CEANOTHUS L. New Jersey Tea

Habit—Low, deciduous shrubs. **Twigs**—Greenish to brownish gray, short pubescent. Lenticels inconspicuous. Pith white, rather large. **Leaf Scars**—Alt., more than two-ranked, half oval. Bundle scars rather irregular, one, or broken into three. Stipular scars narrow and small. **Buds**—Solitary, no definite terminal bud, gray to brown, very hairy, about two to four bud scales visible, the first pair at least three-fourths the bud length. **Bud Content**—Stipules present at sides of lvs., vernation straight to conduplicate. **Leaf Remnants**—Simple, pinnately veined, crenate-serrate, pubescent beneath. **Fruit Remnants**—Nutlets usually fallen leaving a three-lobed saucer-shaped receptacle in corymbose panicles.

1. Remains of the flower cluster on a long stalk; fruit 5 to 6 mm. in diameter, the seeds usually smooth; stems usually clustered, sometimes over 60 cm. high. —*C. americanus* L.
1. Remains of the flower cluster on a short stalk, the fruit 4 to 5 mm. long with seeds usually pitted; stems usually single, seldom over 60 cm. high.
   2. Twigs sparingly hairy; rather rare. —*C. ovatus* Deaf.
   2. Twigs densely pubescent; more common. —*C. ovatus pubescens* Torr. & Gray.

Family VITACEAE

VITIS L. Grape

Habit—Deciduous climbers. **Twigs**—Tendrils opposite some of the leaf scars, brownish, striate or somewhat angled, becoming flaky

barked. Lenticels not conspicuous. Pith moderate to large, tan to brown, with solid partitions at the nodes (in ours). Tracheal tubes and wood rays large. **Leaf Scars**—Alt., two-ranked or somewhat obscurely so, oval, half-round to crescent-shaped. Bundle scars several in a C-shaped series. Stipular scars rather large. **Buds**—Solitary or collaterally branched, brownish, conical, obtuse, with two to four scales. **Bud Content**—Lvs. usually woolly on the back, ovate, serrate, vernation straight but edges appear plicate. **Leaf Remnants**—Broadly ovate, often three lobed, palmately veined. **Fruit Remnants**—Purple or blue black berry.

1. Twigs woolly pubescent; strongly angled. —*V. cinerea* Engelm.
1. Twigs glabrous or sparingly puberulent, terete or very weakly angled.
   2. Diaphragm at the node thin, under 1 mm. thick; very common. —*V. vulpina* L.
   2. Diaphragm over 1.5 mm. thick; rare except in cultivation.
      3. Either a tendril or flower cluster remains at every node; cult., not native here; lvs. tomentose beneath. —**V. labrusca* L.
      3. Tendrils and flower remnants absent from every third node; native but rare in Iowa. Lvs. glaucous beneath. —*V. Lecontiana* House.

The genus Vitis needs more study in this state. *V. aestivalis* Michx. and *V. rubra* Michx. have been reported as occurring in this state, and other species may occur.

AMPELOPSIS Michx.

Habit—Deciduous twiners. **Twigs**—Soft-wooded, tendrils opposite some of the leaf scars; twigs glabrous, straw-colored. Lenticels brown. Pith white, sometimes slightly angled, developing ingrowing partitions from sides. **Leaf Scars**—Alt., round. Bundle scars many, in a ring. Stipular scars long and narrow. **Buds**—Small, often lacking. **Leaf Remnants**—Large, three-lobed, palmately veined. **Fruit Remnants**—Berry, changing from pale to blue, borne in cymes.

—**A. brevipedunculata* Koehne.

PARTHENOCISSUS Planch. Virginia Creeper; Boston Ivy

Habit—Deciduous, usually climbing. **Twigs**—Climbing by tendrils bearing at the tip flat adhesive discs, twigs slender to moderate, often twisted with shortened internodes, brownish to gray, glabrous. Lenticels elongated, very conspicuous. Pith greenish, rather large, somewhat firmer at the nodes. **Leaf Scars**—Alt., usually two-ranked, rather large, half-round to round, about parallel to the twig. Bundle scars rather indistinct but about ten to twelve. Stipular scars long and narrow. Tendrils usually absent from every third node. **Buds**—Usually solitary, short conical, brownish, with two to four bud scales visible.

Bud Content—Lvs. simple, leaf with plicate edges or palmately compound with conduplicate lfts., glabrous. **Leaf Remnants**—Simple or compound. **Fruit Remnants**—Blue-black drupe in cymes.

1. Lvs. in the bud simple but mostly 3-lobed; tendrils usually under 3 cm. in length; not native. —**P. tricuspidata* Planch.
1. Lvs. in the bud palmately compound, of 5 lfts.; tendrils often over 3 cm. long; native as well as cultivated.
   2. Tendrils with 3 to 5 branches, rarely with adhesive discs. —*P. vitacea* Hitchc.
   2. Tendrils with 5 to 12 branches, adhesive discs present. —*P. quinquefolia* Planch.

Another member of the family Vitaceae, *Cissus Ampelopsis* Pers., has been reported in southern Iowa but it is very infrequent.

Family TILIACEAE

TILIA L. Basswood; Linden

Habit—Deciduous trees, bark of young stems smooth and dark-gray, becoming fissured in long, rather narrowed ridges. **Twigs**—Rather slender to moderate, somewhat zigzag. Lenticels rather large but not very conspicuous. Pith at first pale, becoming tan or light-brown, small to moderate, often somewhat angled. Bark with a circle of triangles in section. **Leaf Scars**—Alt., two-ranked, half-round to half-elliptical. Bundle scars three or in three groups but sometimes scattered. Stipular scars unequal, one much longer. **Buds**—Usually solitary, the end bud lacking, obliquely unsymmetrical, with two to four obtuse, thick bud scales visible. **Bud Content**—Lvs. hairy, oblique, serrate, the inner scales probably stipules. **Leaf Remnants**—Broad, cordate at base, palmately veined. **Fruit Remnants**—Rather small, nut-like, in cymes from a leaf-like bract.

1. Twigs rather stout, usually over 3 mm. in diameter.
   2. Buds reddish or reddish-green, glabrous; native and commonly planted. —*T. glabra* Vent.
   2. Buds reddish-brown, sparingly pubescent near apex, sometimes stellate; not native. —**T. heterophylla* Vent.
1. Twigs rather slender, rarely over 3 mm. in diameter, except on shoots.
   3. Twigs and buds with scattered hairs; lvs. in bud whitish hairy. —**T. platyphyllos* Scop.
   3. Twigs and buds glabrous; lvs. in bud brown or tan, hairy. —**T. cordata* Mill

GREWIA L.

Habit—Deciduous shrubs. **Twigs**—Rather slender, gray or olive, densely stellate. Lenticels light, rather conspicuous. Pith white, mod-

erate. **Leaf Scars**—Alt., two-ranked, oval. Bundle scars many, as an oval ring. Stipules remaining. **Buds**—Solitary, small, no definite scales visible, densely pubescent, the end bud absent. **Bud Content**—Lvs. whitish hairy with stipules at sides, vernation conduplicate near tip. Flower cluster often present near end as an umbel. **Leaf Remnants**—Simple, ovate, doubly serrate or dentate, appearing palmately veined, stellate-hairy beneath. **Fruit Remnants**—Orange to red, one seeded sub-globose drupe. —**G. parviflora* Bge.

Family MALVACEAE

HIBISCUS L. Shrubby Althaea

Habit—Deciduous shrubs. **Twigs**—Moderate, enlarged near the end and at node, somewhat two-ridged from leaf scars, gray to gray-green. Lenticels raised, pale, fairly conspicuous. Pith whitish with a greenish border, moderate to small. **Leaf Scars**—Alt., more than two-ranked, often clustered near the end of the twig, half oval, raised. Bundle scars about four. Stipular scars or thread-like stipules at sides of scars. **Buds**—Usually replaced by scars of inflorescence. **Leaf Remnants**—Ovate to rhombic, rather three-lobed, palmately veined. **Fruit Remnants**—A five-celled capsule. —**H. syriacus* L.

Family GUTTIFERAE

HYPERICUM L. St. John's-wort

Habit—Deciduous shrubs, narrow, partly developed lvs. often present. **Twigs**—Rather slender, four-ridged from below the leaf scars, two from the center of the scar and two from a point between scars, bark of older twigs shreddy. Lenticels not conspicuous. Pith greenish to brown, small to moderate, spongy to excavated. **Leaf Scars**—Opposite, triangular, little raised. Bundle scar one. Stipular scars none but opposite leaf scars connected by a transverse ridge. **Buds**—Seldom present but replaced by a cluster of lvs. or a branch. **Bud Content**—Partly developed buds have linear to lanceolate lvs. covered with small punctate dots. **Leaf Remnants**—Linear-oblong to lanceolate, the margins entire. **Fruit Remnants**—Septicidal capsules in corymbs or cymes.

This is a hard genus in which to separate the species in winter condition as well as at any other time. Only one, *H. prolificum* L., is found native and it differs from the cultivated forms studied by having longer capsules, often 11 mm. long.

Family TAMARICACEAE

TAMARIX L. Tamarisk

Habit—Deciduous shrubs or small trees. **Twigs**—Slender, the ends usually drying, glabrous, reddish-brown to light-brown. Lenticels on older wood fairly conspicuous. Pith greenish to white, small and not central. **Leaf Scars**—Lacking because of the persistent leaf bases, these are alt., and more than two-ranked. **Buds**—Small, light-brown to reddish-brown, glabrous, solitary or multiple, obtuse with about three to four bud scales visible. **Bud Content**—Too small for detail. **Leaf Remnants**—Small, scale-like, decurrent. **Fruit Remnants**—A three to five valved capsule. —**T. odessana* Stev.

This seems to be the common species in this region. Two other species *T. parviflora* DC. and *T. gallica* L. have been reported and might be expected in Iowa.

Family THYMELAEACEAE

DAPHNE L.

Habit—Small, evergreen or deciduous shrubs. **Twigs**—Moderate, gray to brown, puberulent. Pith greenish, small. Wood rather soft. **Leaf Scars**—Alt. to opposite, more than two-ranked, half-round to crescent-shaped. Bundle scar one. Stipular scars none. **Buds**—Solitary or mostly so, slightly pubescent, with six to eight bud scales visible on the terminal bud. **Bud Content**—Scales grade into ciliate, entire, pinnately veined lvs., vernation straight. Flowers in center of bracts or lvs. in parts of four. **Leaf Remnants**—Entire, glabrous. **Fruit Remnants**—A one-seeded drupe.

1. Deciduous. —**D. Mezereum* L.
1. Evergreen. —**D. Cneorum* L.

DIRCA L. Leatherwood

Habit—Small deciduous shrubs. **Twigs**—Rather slender, the upper nodes swollen, rubbery when bent, light brown, glabrous. Lenticels rather conspicuous. Pith whitish, very small, spongy. Wood with prominent rays and thick, tough bark. **Leaf Scars**—Alt., typically two-ranked, annular, almost encircling the bud. Bundle scars five or more. Stipular scars none. **Buds**—Appear solitary, no terminal bud, brown silky-hairy with indistinct scales. **Bud Content**—Lvs. glabrous but ciliate, simple, entire, pinnately veined with straight vernation. Flowers with lvs. **Leaf Remnants**—Elliptical to obovate, entire. **Fruit Remnants**—Drupe about 8 mm. long. —*D. palustris* L.

Family ELAEAGNACEAE

SHEPHERDIA Nutt. Buffalo Berry

Habit—Deciduous shrubs or small trees. **Twigs**—Moderate, silvery or brown because of small peltate scales, the twig often ending in a spine. Lenticels inconspicuous. Pith brown, small to moderate. **Leaf Scars**—Opposite, half-round, somewhat raised. Bundle scar one. Stipular scars none. **Buds**—Solitary or multiple through branching, usually appressed and covered with silvery or brown scales like the twig, stalked, with about four valvate bud scales visible, the first two the length of the bud. **Bud Content**—Lvs. simple, entire, scaly, with straight vernation. Flowers not in bud scales but closed with four sepals, no petals, and seven or eight stamens. **Leaf Remnants**—Pinnately veined, rather small, covered with peltate scales on one or both sides. **Fruit Remnants**—Reddish drupe.

1. Some of scales reddish-brown. —**S. canadensis* Nutt.
1. Scales all silvery, none reddish-brown. —*S. argentea* Nutt.

ELAEAGNUS L. Oleaster; Russian Olive

Habit—Deciduous shrubs or trees. **Twigs**—Slender to moderate, with silvery or brown peltate scales, especially near the end. Lateral thorns often present. Lenticels inconspicuous. Pith pale to brown, moderate, sometimes irregular in section. **Leaf Scars**—Alt., more than two-ranked, half round, somewhat raised. Bundle scar one. Stipular scars none. **Buds**—Silvery or brown from peltate scales, about two to six bud scales visible, the first scale at least one-half the bud length. **Bud Content**—Scales grade into the peltate, scaly lvs., vernation straight. **Leaf Remnants**—Simple, entire, rather small, pinnately veined, covered at least below with scales. **Fruit Remnants**—Drupe-like with scales.

1. Scales never brownish; often thorny and tree-like. —**E. angustifolia* L.
1. Some of scales on twig or bud brownish; thornless shrubs.
   2. Terminal bud with some silvery scales, especially at the tip; high shrubs, often over 3 m. tall. —**E. argentea* Pursh.
   2. Terminal bud with brownish scales throughout; usually a low shrub, less than 3 m. tall. —**E. multiflora* Thunb

Family ARALIACEAE

ACANTHOPANAX Miq.

Habit—Deciduous, small trees with trunks often spiny, or shrubs. **Twigs**—Gray to brown, glabrescent, spiny. Lenticels conspicuous. Pith white, often very large. **Leaf Scars**—Alt., more than two-ranked,

narrowly crescent- to V-shaped. Bundle scars mostly five to twelve. Stipular scars none. **Buds**—Solitary, gray-tan, conical to ovoid, about two or three bud scales visible, the first about the length of bud. **Bud Content**—Lvs. compound or lobed. **Leaf Remnants**—Palmately lobed or compound. **Fruit Remnants**—Berries borne in panicles.

1. Spines scattered on the internodes; typically tree-like. —**A. ricinifolius* Seem.
1. Spines limited to nodes; shrubs. —**A. Sieboldianus* Mak.

ARALIA L. Hercules Club

Habit—Deciduous, large shrubs or small trees, bark of trunk very spiny. **Twigs**—Very stout, straw-colored, spiny, especially just below the nodes. Lenticels brown, elongated and rather conspicuous. Pith white, very large. Twigs exuding a transluscent liquid when cut, which quickly hardens. **Leaf Scars**—Alt., more than two-ranked, U-shaped, almost encircling the twig. Bundle scars many. Stipular scars none. **Buds**—Solitary, placed at some distance below the scar, light brown, glabrous, almost appressed, scales few. **Bud Content**—Inner scales and lvs. with transverse narrow red stripes, lvs. decompound, mostly rachis. **Leaf Remnants**—Doubly pinnately compound, very large, with large, usually prickly petiole. **Fruit Remnants**—Black and berry-like, about 6 mm. in diameter, in panicles. —**A. spinosa* L.

Family CORNACEAE

CORNUS L. Dogwoods

Habit—Deciduous shrubs or rarely small trees. **Twigs**—Slender to moderate. Pith whitish to brown, moderate to large, sometimes angled in section, sometimes spongy. **Leaf Scars**—Alt. and more than two-ranked or opposite, crescent- or flattened U-shaped. Bundle scars three. Stipular scars none but opposite leaf scars connected by a transverse ridge. **Buds**—Terminal bud present, and often swollen at the base or along its entire length by the flower cluster inside, solitary, often stalked, the first two bud scales the length of the bud and often covering it. **Bud Content**—Lvs. simple, entire, at least the outer pubescent, pinnately veined, the vernation various, usually involute near the ends. Flowers in a globose cluster. **Leaf Remnants**—Entire, ovate to elliptical. **Fruit Remnants**—Drupes, usually in flat topped cymes.

1. Leaf scars alt., usually crowded out near the end of the twig. —*C. alternifolia* L.
1. Leaf scars opposite, not crowded near the twig end.

2. **Lateral buds of young twigs covered by raised leaf scar base; enlarged flower buds biscuit-shaped, rather flattened from end. —*C. *florida* L.**
2. **Lateral buds not concealed; none of buds flattened biscuit-shaped.**
   3. **Lateral buds divergent at about a twenty degree angle to the twig; some of buds much enlarged, obtuse at end. —*C. *mas* L.**
   3. **Lateral buds appressed; none of the buds greatly enlarged, the flower buds rather pointed.**
      4. Twigs bright greenish-yellow in color. —*C. *stolonifera flaviramea* Rehd.
      4. Twigs not greenish-yellow.
         5. Twigs bright coral red. —*C. *alba sibirica* Loud.
         5. Twigs dark red to grey in color.
            6. Twigs gray to brownish-gray; fruit remains in an elongated panicle-like cyme. —C. *racemosa* Lam.
            6. Twigs not grayish; cymes flat (rest of key only approximate).
               7. Pith soon becoming tan or brown.
                  8. Twigs sparingly puberulent; leaf remnants not scabrous above; fruit light blue. —C. *Amomum* Mill.
                  8. Twigs heavily appressed-pubescent; leaf remnants scabrous above, fruit white. —C. *asperifolia* Michx.
               7. Pith pale, not tan or brown.
                  9. Buds dark brown, silky with no shade of gray. —*C. *sanguinea* L.
                  9. Buds gray to brownish.
                     10. Twigs deep blood-red, the lenticels pale, rather conspicuous; leaf remnants elliptical with four to five pairs of veins. —C. *stolonifera* Michx.
                     10. Twigs reddish to greenish-red, lenticels inconspicuous; leaf remnants broadly ovate to sub-orbicular with about eight pairs of veins. —C. *rugosa* Lam.

This genus has a few well marked species, but many are hard to separate in any condition. The last part of the key is only an approximation and should be used with caution.

Family CLETHRACEAE

CLETHRA L. White Alder

Habit—Deciduous shrubs. **Twigs**—Slender, yellowish to tan, scurfy pubescent. Pith white to green, rather large, sometimes obscurely angled. **Leaf Scars**—Alt., more than two-ranked, somewhat triangular. Bundle scar one and raised. Stipular scars none. **Buds**—Terminal bud large, densely yellowish pubescent, with about three bud scales visible on the terminal bud, these scarred at tip. **Bud Content**—Lvs. long-ovate, acuminate, entire, densely hairy outside, pinnately veined, vernation straight, except as wrapped around the inner mass. **Leaf Remnants**—Obovate to oblong, sharply serrate, pubescent be-

neath. **Fruit Remnants**—Sub-globose capsule about 3 mm. in diameter borne in upright racemes. —**C. alnifolia* L.

Family ERICACEAE

RHODODENDRON L.

Habit—Evergreen or deciduous shrubs. **Twigs**—Slender to stout, pubescent. Lenticels inconspicuous. Pith pale to green, sometimes angled. **Leaf Scars**—Alt., more than two-ranked, crescent- or shield-shaped. Bundle scars one or broken into more. Stipular scars none. **Buds**—Solitary, often minute, terminal flower buds often much enlarged and with many scales, although sometimes partly hidden in the lvs. **Bud Content**—Vernation revolute. **Leaf Remnants**—Simple, entire, pinnately veined. **Fruit Remnants**—Septicidal capsule.

This genus is not native here and is rarely planted in Iowa. The species have been extensively hybridized and are difficult. Those located fall into two groups, one with small leaves with flat appressed hairs such as *R. Simsii* Planch. and *R. yedoense* Maxim., and the other with large leaves, the hairs not flattened such as *R. catawbiense* Michx. and *R. maximum* L.

KALMIA L. Mountain Laurel

Habit—Evergreen to deciduous shrubs. **Twigs**—Rather small to moderate. Lenticels inconspicuous. Pith greenish to brown, moderate to large. **Leaf Scars**—Often whorled and clustered near the end of the twig, but sometimes alt. and more than two-ranked. Bundle scar one. Stipular scars none. **Buds**—Very small, puberulent, appressed, with about two bud scales visible. **Bud Content**—Lvs. very small, the vernation straight. **Leaf Remnants**—Lanceolate to elliptical, entire, pinnately veined. **Fruit Remnants**—A sub-globose, five-valved capsule.

1. Lvs. entire to acuminate, 8 to 10 cm. long, usually alt., but sometimes opposite or whorled; fruit in terminal corymbs. —**K. latifolia* L.
1. Lvs. mostly obtuse, smaller, usually less than 6 cm. long, usually whorled; fruits in lateral corymbs. —**K. angustifolia* L.

PIERIS D. Don.

Habit—Evergreen shrubs. **Twigs**—Slender to moderate, rather appressed hairy and scurfy. Lenticels not conspicuous. Pith rather small, pale, round to triangular. **Leaf Scars**—Alt., more than two-ranked, half round, little raised. Bundle scar one. Stipular scars none. **Buds**—Small, slightly ciliate, the end bud not ordinarily pres-

ent, about two to four somewhat keeled and long pointed bud scales visible. **Bud Content**—Scales grade into entire, glabrous, pinnately veined lvs., the vernation straight but with the long leaf tips rather pinched together. **Leaf Remnants**—Oblong, acute, crenate-serrulate. **Fruit Remnants**—Often present as a globose five-valved capsule, or sometimes an unopened flower cluster. —**P. floribunda* Benth. & Hook.

ARCTOSTAPHYLOS Adans. Bearberry

Habit—Prostrate evergreen shrubs with rooting branches. **Twigs**—Slender, slightly three angled, short hairy, brownish to gray. Lenticels inconspicuous. Pith pale, moderate, often somewhat angled. **Leaf Scars**—Alt., more than two-ranked, half elliptical. Bundle scar one. Stipular scars none. **Buds**—Terminal bud slightly larger, ovoid, blunt, puberulent, brownish, with five to seven bud scales visible. **Bud Content**—Lvs. glabrous with straight vernation. **Leaf Remnants**—Obovate to oblong, entire, cuneate at base, obtuse at tip, glabrous except for ciliation. **Fruit Remnants**—Red drupe about 6 to 8 mm. in diameter. Very rare. —*A. uva-ursi* Spreng.

GAYLUSSACIA HBK. Huckleberry

Habit—Rather low, deciduous shrubs. **Twigs**—Slender, twiggy, light brown, short tomentose. Lenticels not conspicuous. Pith pale, rather small. **Leaf Scars**—Alt., more than two-ranked, crescent-shaped. Bundle scar one. Stipular scars none. **Buds**—No terminal bud, the laterals light brown to reddish, the edges often gray, with yellow resin dots near the tip. **Bud Content**—Scales grade into simple, entire, pinnately veined lvs., which are covered with yellow dots, vernation straight. Flowers in leaf axils, with five sepals, ten stamens and one style. **Leaf Remnants**—Elliptical, with small yellow resin dots beneath. **Fruit Remnants**—Lustrous, edible, black berry about 6 to 8 mm. in diameter. —*G. baccata* K. Koch.

VACCINIUM L. Blueberry; Deerberry

Habit—Low, deciduous shrubs. **Twigs**—Slender, reddish brown, with raised white dots covering the twig. Pith pale, moderate. **Leaf Scars**—Alt., more than two-ranked, half-round to elliptical, little raised. Bundle scar one. Stipular scars none. **Buds**—No end bud, laterals reddish-brown, with lighter margins, glabrescent, with about seven to ten somewhat keeled bud scales visible. **Bud Content**—Scales grade into entire lvs., vernation straight and imbricate. Flowers in the bud with lvs. and with five sepals, five petals, ten stamens and with

a capitate stigma. **Leaf Remnants**—Simple, small, entire, pinnately veined. **Fruit Remnants**—A berry.

1. Twigs pubescent; some of bud scales attenuated at tip, the buds rather appressed. —*V. stamineum* L.
1. Twigs glabrous; bud scales keeled but not attenuated, the buds rather divergent. —*V. vacillans* Soland.

Another species *V. pennsylvanicum* Lam. has been reported for eastern Iowa.

Family EBENACEAE

DIOSPYROS L. Persimmmon

Habit—Deciduous tree, with dark bark tending to separate into square, thick plates. **Twigs**—Moderate, light brown, glabrous and often somewhat glaucous. Lenticels lighter, fairly conspicuous. Pith whitish, often becoming spongy or chambered in older twigs. **Leaf Scars**—Alt., two- or more than two-ranked, half-round, raised as a shelf for the base of the bud. Bundle scar one, rather C-shaped. Stipular scars none. **Buds**—Solitary, appressed, brown, obtuse, with about two bud scales visible, the first the length of the bud. **Bud Content**—Lvs. entire, hairy outside on the rib, vernation straight. **Leaf Remnants**—Simple, pinnately veined, glabrous. **Fruit Remnants**—Large, globose berry, yellowish to pale orange in color, about 2 to 3.5 cm. in diameter. —**D. virginiana* L.

Family SYMPLOCACEAE

SYMPLOCOS Jacq. Sweetleaf

Habit—Deciduous shrubs or small trees. **Twigs**—Moderate to slender, gray, scurfy, somewhat two-ridged from leaf scars. Lenticels not conspicuous. Pith becoming brown, moderate, chambered. **Leaf Scars**—Alt., two-ranked, broadly crescent-shaped, somewhat raised. Bundle scars usually as one transverse line but sometimes may be broken into more. Stipular scars none. **Buds**—Solitary or superimposed, short-ovoid, brownish to gray, sparingly pubescent, about six to eight obtuse bud scales visible. **Bud Content**—Scales grade into somewhat pubescent lvs., vernation straight, but cupped around the inner mass. **Leaf Remnants**—Simple, sharply serrate, elliptical to obovate, pinnately veined. **Fruit Remnants**—A drupe.

—**S. paniculata* Wall.

Family STYRACACEAE

HALESIA Ellis. Silver Bell-tree

Habit—Deciduous trees, bark separating into appressed scales.

Twigs—Rather slender, somewhat zigzag, older twigs with silky-shreddy bark. Lenticels pale, transversely elongated on older twigs. Pith whitish, rather small, inclined to be chambered on older twigs or at least spongy. **Buds**—Often superimposed, lower one smaller, brownish, somewhat puberulent, with about four somewhat keeled bud scales visible. **Bud Content**—Vernation straight but cupped around inner mass. Flower buds separate with about three flowers, with a four parted perianth, ten stamens, and one style. **Leaf Remnants**—Simple, serrulate, rather stellate-hairy beneath, elliptical to oblong-ovate, pinnately veined. **Fruit Remnants**—Dry, four winged oblong drupe.

—**H. carolina* L.

Family OLEACEAE

FRAXINUS L. Ash

Habit—Deciduous trees. **Twigs**—Stout, often rather square in section. Pith whitish. **Leaf Scars**—Opposite, half round, sub-elliptical to crescentic. Bundle scars as a C-shaped line. Stipular scars lacking or very indistinct. **Buds**—Solitary or superimposed, the lower smaller, lateral buds rounded at the tip, with two to three pairs of scurfy bud scales visible. **Bud Content**—Scales with leaf vestiges at tip that grade into pinnately compound rather woolly lvs., vernation of lfts. conduplicate. **Leaf Remnants**—About five to eleven lfts. **Fruit Remnants**—A one-sided winged nutlet.

1. Twigs four-angled, rather square in section; buds dark gray in color. —*F. quadrangulata* Michx.
1. Twigs not angled; buds brownish or blue-black.
   2. Buds blue-black, the bud scales of terminal bud apiculate; first pair of lateral buds usually remote from the end of the twig.
      3. Leaf scars definitely half-round; buds very dark blue-black; not native; branches often pendulous. —**F. excelsior pendula* Ait.
      3. Leaf scars usually somewhat vertically elliptical; buds more brownish-black; native; branches not drooping. —*F. nigra* Marsh.
   2. Buds brown, bud scales of terminal bud not strongly apiculate; first pair of lateral buds often crowded out near the end of the twig.
      4. Twigs typically downy-pubescent. —*F. pennsylvanica* Marsh.
      4. Twigs glabrous.
         5. Leaf scars usually deeply concave on the top; often rather U-shaped. —*F. americana L.*
         5. Leaf scars typically straight across on the top or but slightly concave. —*F. pennsylvanica lanceolata* Sarg.

FORSYTHIA Vahl. Golden-bell

Habit—Deciduous, rather loosely spreading shrubs. **Twigs**—Mod-

erate, greenish to yellow-brown, glabrous, two-ridged from each leaf scar. Lenticels raised and conspicuous. Pith white to tan, either chambered or excavated. **Leaf Scars**—Opposite, half-round to shield-shaped, slightly raised. Bundle scar one as a short transverse line. Stipular scars none. **Buds**—Solitary or becoming multiple, elongated fusiform or lanceoloid, with twelve to eighteen opposite, four-ranked, somewhat keeled bud scales visible. **Bud Content**—Vernation straight or nearly so. Flower buds separate, one flower to a bud, four sepals, four petals, two stamens, and a two lobed stigma. **Leaf Remnants**—Simple, pinnately veined. **Fruit Remnants**—An ovoid, two celled capsule.

1. Pith solid at the nodes.
   2. Pith of internode chambered. —*X *F. intermedia* Zabel.
   2. Pith of internodes excavated. —**F. auspensa* Vahl.
1. Pith of nodes not solid, usually chambered throughout or rarely hollow throughout. —**F. viridissima* Lindl.

SYRINGA L. Lilac

Habit—Tall, deciduous shrubs or rarely trees. **Twigs**—Slender to stout, often four-ridged. Lenticels usually conspicuous. Pith whitish, moderate to large. **Leaf Scars**—Opposite, crescent, shield-shaped or half-round, rather small, definitely raised, forming a sort of shelf on which the bud rests. Bundle scars as a transverse line. Stipular scars none. **Buds**—Solitary or rarely collateral with about six to eight bud scales visible in four ranks, occasionally more, terminal bud present or absent. **Bud Content**—Lvs. ovate, entire, at most ciliate, pinnately veined, vernation straight but leaf keeled. **Leaf Remnants**—Simple. **Fruit Remnants**—An oblong, loculicidal capsule borne in panicles.

1. Typically shrubs, rarely if ever trees.
   2. Terminal bud normally present, often containing the flower cluster of next year, fruit panicle terminal and grading into an ordinary twig.
      3. Twigs and bud scales glabrous.
         4. Twigs terete, not longitudinally ridged. —**S. amurensis* Rupr.
         4. Twigs ridged from the leaf scars.
            5. Twigs gray to olive; bud scales rather fleshy and not strongly keeled. —**S. yunnanensis* Franch.
            5. Twigs brown to gray; bud scales becoming rather dry and strongly keeled, boat-shaped. —**S. persica* L.
      3. Twigs and bud scales pubescent or puberulent.
         6. Bud scales definitely keeled; buds ovoid.
            7. Outer bud scales of terminal bud keeled and boat-shaped, long pointed; twigs gray to olive-green, about 5 mm. in diameter or over; fruit often over 1.2 mm. long. —**S. villosa* Wahl.

7. Outer bud scales of terminal bud somewhat keeled but not strongly boat-shaped, not long pointed; twigs gray to brown, rarely up to 5 mm. in diameter; fruit seldom up to 1.2 mm. long. —**S. Josikaea* Jacq.
6. Bud scales not or only slightly keeled; buds short and conical. —**S. Wolfii* Schneid.
2. Terminal bud normally absent or very small, the lateral buds often containing a flower cluster; fruit panicle not gradually grading into a twig.
8. Scales of lateral bud dry, laterally compressed, the outer spreading, terminal bud occasionally present. —**S. persica* L.
8. Scales of lateral buds fleshy, not strongly compressed laterally, nor spreading; terminal bud rarely present.
9. Bud scales dark brown with tan-colored, scarious margins. —**S. oblata dilatata* Rehd.
9. Bud scales uniform in color, edges not conspicuouly lighter.
10. Twigs conspicuously four ridged, the lenticels rarely present on the side of the twig just above the bud. —**S. chinensis* Willd.
10. Twigs at most very slightly ridged, the lenticels often above the bud.
11. Buds puberulent. —**S. microphylla* Diels
11. Buds glabrous or nearly so.
12. Twigs slender; buds seldom over 5 mm. long; not common. —**S. amurensis* Rupr.
12. Twigs moderate; buds larger; our most common species of lilac. —**S. vulgaris* L.
1. Typically a tree. —*S japonica* Decne.

FORESTIERA Poir.

Habit—Deciduous shrubs. **Twigs**—Many short, divergent, almost spine-like slender twigs, gray, puberulent near the tip. Lenticels light, rather conspicuous. Pith pale or sometimes becoming tan, moderate. **Leaf Scars**—Opposite, half-round, only slightly raised. Bundle scar one. Stipular scars none. **Buds**—Superimposed, the upper larger, gray-brown, ten to fourteen somewhat ciliate bud scales visible in four ranks. **Bud Content**—Inner scales green at base and purplish-red near tip grading into simple, entire, ovate, pinnately veined lvs., the vernation straight but the tips of the leaf somewhat pinched together. **Leaf Remnants**—Oblong-obovate to oblanceolate, crenate-serrulate, the petiole very short. **Fruit Remnants**—A black one- to two-seeded drupe, about 4 to 5 mm. long. —**F. neo-mexicana* Gray.

CHIONANTHUS L. Fringe-tree

Habit—Deciduous small trees or large shrubs. **Twigs**—Moderate to stout, rather four-sided, greenish-gray to brown, pubescent. Lenticels large, oval, longitudinally elongated with acute ends, conspicuous. Pith white, moderate to large. **Leaf Scars**—Opposite, oval, flattened at the top to half round, almost parallel to the twig. Bundle scars

one in a C-shaped line. Stipular scars none. **Buds**—Often superimposed, the upper one larger, gray to brown, sparingly pubescent, rather four-sided, with six to eight keeled and pointed bud scales visible in four ranks. **Bud Content**—Inner scales dark-brown below and lighter above often rosy-colored, but the line between sharp. Lvs. white-downy at tip of larger ones, vernation straight. Flower cluster in center of bracts or lvs. **Leaf Remnants**—Oblong, entire, pinnately veined. **Fruit Remnants**—Dark blue drupes 1.5 to 2 cm. long, borne in loose panicles on the pistillate tree. —**C. virginica* L.

LIGUSTRUM L. Privet

Habit—Shrubs, deciduous but sometimes holding their foliage. **Twigs**—Rather slender, gray to olive, at least somewhat pubescent. Pith whitish, moderate, often slightly angled. **Leaf Scars**—Opposite, half-round, definitely raised, small. Bundle scar one. Stipular scars none. **Buds**—Usually solitary, somewhat pubescent, with opposite, four-ranked bud scales. **Bud Content**—Lvs. simple, entire, pinnately veined, with straight vernation. **Leaf Remnants**—Petiole short, 1 to 3 mm. long. **Fruit Remnants**—Black, berry-like drupe often present.

1. Twigs only minutely puberulent; bud scales keeled, and at most ciliate; lvs. glabrous below; common. —**L. vulgare* L.
1. Twigs definitely pubescent but scales slightly if at all keeled, definitely pubescent; lvs. pubescent on veins beneath; not common.
   2. Lenticels rather conspicuous; outer bud scales not at all keeled —**L. amurense* Carr.
   2. Lenticels inconspicuous; outer bud scales usually slightly keeled —**L. obtusifolium* Sieb. & Zucc.

Family LOGANIACEAE

BUDDLEIA. Butterfly-bush

Habit—Shrubs, ours deciduous. **Twigs**—Slender, light brown to straw-colored. Lenticels not conspicuous. Pith whitish, small to moderate. **Leaf Scars**—Opposite, or alt. and more than two-ranked, oval to crescent-shaped, often definitely raised. Bundle scar one. Stipular scars none. **Buds**—Solitary, sometimes superimposed, the upper commonly developing into a branch, small, with two to four bud scales visible, the first two about the length of the bud. **Leaf Remnants**—Simple, oblong to lanceolate, pinnately veined, rather tomentulose beneath. **Fruit Remnants**—Oblong to ovoid capsules.

1. Lvs. opposite. —**B. Davidi* Franch.
1. Lvs. alternate. —**B. alternifolia* Maxim.

Family VERBENACEAE

VITEX L.

Habit—Deciduous shrubs or sub-shrubs. **Twigs**—Soft-wooded, peppery aromatic, square in section with obtuse or sharp angles, light brown to tan, puberulent. Lenticels not conspicuous. Pith moderate, white, four-sided. **Leaf Scars**—Opposite, U-shaped, little raised. Bundle scar one as a transverse line. Stipular scars none but opposite leaf scars often connected by a transverse ridge. **Buds**—No terminal bud, the laterals often superimposed, the upper commonly developing the first year, tan or light brown, tomentose, two to four scales indistinctly visible. **Bud Content**—No detail but lvs. appear compound. **Leaf Remnants**—Palmately compound of three to seven lfts. **Fruit Remnants**—Small drupes with a pungent flavor, borne in panicles.

1. Inflorescence remains as a loose panicle; fruit or calyx remains over 2 mm. wide; twigs rounded at the angles. —**V. agnus-castus* L.
1. Inflorescence remains a narrow panicle; fruit or calyx remains less than 2 mm. wide; twigs with acute angles. —**V. Negundo* L.

Family SOLANACEAE

SOLAMUM L. Nightshade

Habit—Deciduous twiners. **Twigs**—Soft-wooded, rather two-ridged from the leaf scars, green, slightly pubescent. Lenticels on older wood raised, rather conspicuous. Pith pale to greenish, rather large, often spongy to excavated. **Leaf Scars**—Alt., more than two-ranked, round but flattened on the top, raised. Bundle scar one. Stipular scars none. **Buds**—Solitary, small, rather globose, hairy, with about three to six indistinct scales. **Bud Content**—Scales grade into thick, entire lvs., vernation straight. **Leaf Remnants**—Ovate, entire, often lobed at base. **Fruit Remnants**—Red berries borne in cymes.

—**S. Dulcamara* L.

LYCIUM L. Box-thorn; Matrimony-vine

Habit—Deciduous, scrambling or often vine-like. **Twigs**—Slender to moderate, often ridged from below the leaf scars, gray, glabrescent. Lenticels inconspicuous. Pith greenish to white, moderate to large, somewhat spongy. **Leaf Scars**—Alt., more than two-ranked, half-round to crescent-shaped. Bundle scar one. Stipular scars none. **Buds**—Often multiple in collateral aggregates, short-globose and small, seeming partly concealed. **Bud Content**—Scales grade into simple, entire, pinnately veined, somewhat ciliate lvs., vernation straight. **Leaf Remnants**—Glabrous, light green, sessile or short petioled. **Fruit Remnants**—Reddish, many-seeded berry.

1. Internodes short, twigs very zigzag and tortuous. —**L. pallidum* Miers.
1. Internodes rather long, twigs only slightly zigzag..
   2. Typically scrambling; twigs straw to light-gray in color. —**L. chinense* Mill.
   2. Typically shrubby; twigs straw to dark-gray in color. —**L. halimifolium* Mill.

Family BIGNONIACEAE

CAMPSIS Lour. Trumpet-creeper

Habit—Deciduous, sometimes shrubby but usually climbing by aerial rootlets. **Twigs**—Stout to moderate, glabrous, straw-gray. Lenticels conspicuous. Pith large, pale to light-brown. **Leaf Scars**—Opposite, shield to elliptical in shape. Bundle scars as a C-shaped structure. Stipular scars none but opposite leaf scars usually connected by a transverse ridge. **Buds**—No terminal bud, laterals glabrous, about four to five bud scales visible in four ranks, the first pair about the length of the bud. **Bud Content**—Lvs. small but seem to be compound. **Leaf Remnants**—Pinnately compound of nine to eleven lfts. **Fruit Remnants**—Pod-like capsule, keeled on two sutures, about 16 cm. long and containing winged seeds. —*C. radicans* Seem.

CATALPA L.

Habit—Deciduous small to large trees, with bark separating into scales. **Twigs**—Stout. Lenticels rather large, pale. Pith large, pale. **Leaf Scars**—Whorled, oval to round, parallel to the twig. Bundle scars many in a circle. Stipular scars none. **Buds**—Solitary, small, about four to eight somewhat keeled bud scales visible. **Bud Content**—About eight to ten inner scales. Lvs. simple, entire, vernation straight. **Leaf Remnants**—Large, broadly ovate, entire, cordate, palmately veined. **Fruit Remnants**—Long pod-like capsules.

(Key based on persistent capsules)

1. Crown of tree umbrella shaped. —**C. bignonicides nana* Bur.
1. Crown spreading.
   2. Capsules and twigs slender, under 5 mm. in diameter. —**C. ovata* Don.
   2. Capsules and twigs stouter.
      3. Capsules usually over 8 mm. in diameter, seeds rounded at ends; bark of trunk thick and rough. —**C. speciosa* Warder.
      3. Capsules usually less than 8 mm. in diameter, seeds rather pointed at the ends; bark of trunk thin and flaky-scaled. —**C. bignonioides* Walt.

Family RUBIACEAE

CEPHALANTHUS L. Buttonbush

Habit—Deciduous shrubs. **Twigs**—Moderate, light brown to gray, glabrous. Lenticels raised, elongated, fairly conspicuous. Pith light

brown, fairly large. **Leaf Scars**—Opposite but often whorled, half-round. Bundle scar one as a crescent-shaped line. Stipular scars narrow, often completely connecting opposite leaf scars. **Buds**—Very small, usually solitary, appearing partly concealed, remote from the leaf scar, often in a depressed area. **Bud Content**—Lvs. ovate, entire and acute, the vernation straight. Stipules often present. **Leaf Remnants**—Rather serrate-dentate near the tip. **Fruit Remnants**—Nutlets in a globose head, often present. —*C. occidentalis* L.

Family CAPRIFOLIACEAE

SAMBUCUS L. Elder

Habit—Deciduous shrubs. **Twigs**—Stout, soft-wooded, obscurely angled, straw- to gray-brown, glabrous. Lenticels conspicuous. Pith white or brown, very large. **Leaf Scars**—Opposite, broadly triangular to crescent-shaped, little raised. Bundle scars three to seven. Stipular scars none. **Buds**—Solitary or superimposed, the lower ones smaller, sometimes stalked, with four to eight opposite bud scales visible. **Bud Content**—Scales grade into pinnately compound lvs. with involute lfts. **Leaf Remnants**—Odd pinnate, the lfts. serrate. **Fruit Remnants**—Drupes in flat topped cymes or ovoid panicles.

1. Pith brown; buds ovoid, narrowing in at the base, often stalked, not superimposed. —*S. pubens* Michx.
1. Pith white; buds short, less than 5 mm. long, often superimposed.
   2. Twigs with very large and very conspicuous lenticels; not native. —**S. nigra aurea* Sweet.
   2. Twigs with small, only fairly conspicuous lenticels; native and common. —*S. canadensis* L.

VIBURNUM *L.*

Habit—Shrubs or rarely small trees, our species deciduous. **Twigs**—Slender to moderate, often somewhat angled, sometimes stellate-pubescent. Pith whitish to tan, moderate to large, often angled in section. **Leaf Scars**—Opposite, crescent- to triangular- or V-shaped. Bundle scars three. Stipular scars none but opposite leaf scars connected by a transverse ridge. **Buds**—Solitary, ovoid to oblong, often stalked, the end bud often swollen at the base from the flower cluster, sometimes naked, glabrous, scurfy or stellate-hairy. **Bud Content**—Lvs. simple, vernation plicate or involute. Flowers in center of lvs., usually in the terminal bud. **Leaf Remnants**—Dentate or lobed. **Fruit Remnants**—Drupe with a one-seeded compressed stone, borne in umbel-like or paniculate cymes.

1. End bud present and naked with no evident bud scales, the flower cluster exposed.
   2. Twigs slender, seldom over 2 mm. in diameter; low shrubs; involucre bracts of unopened flower cluster not curving over the top. —**V. Carlesii* Hemsl.
   2. Twigs stouter; tall shrub; involucre bracts curving over and meeting above the flower cluster. —**V. Lantana* L.
1. End bud with evident bud scales visible, or absent entirely.
   3. Buds conspicuously rusty-red scurfy. —**V. rufidulum* Raf.
   3. Buds either not scurfy or the scurf not rusty-red.
      4. Lateral buds oblong-elongated. the terminal bud with a long tip and swollen at the base, hence "flask" shaped, buds scurfy but not stellate-hairy.
         5. Buds definitely brown-scurfy. —**V. cassinoides* L.
         5. Buds becoming gray-scurfy.
            6. Terminal flask-shaped bud often over 16 mm. long, the tip long-extended; often over 8 mm. from the swollen base; twigs long and flexuous. —*V. Lentago* L.
            6. Terminal flask-shaped bud shorter, the tip shorter; twigs usually short and rigid. —*V. prunifolium* L.
      4. Lateral buds not oblong-elongated, ovoid or sub-ovoid in shape, terminal bud not flask-shaped, buds glabrous or stellate-hairy.
         7. Twigs pubescent, usually stellate.
            8. Only two bud scales visible on the bud; twigs heavily stellate-tomentose. —**V. tomentosum* Thunb
            8. More than two bud scales visible; twigs sparingly short stellate-scurfy.
               9. Lateral buds appressed, the ends somewhat curved in toward the twig. —?**V. pubescens* Pursh.
               9. Lateral buds spreading at an angle of ten degrees or more from the twig, not curving in toward the twig. —**V. acerifolium* L.
         7. Twigs glabrous.
            10. Fruit persistent and reddish; buds sub-globose. —**V. Opulus* L.
            10. Fruit either never present or, if so, blue in color; buds ovoid.
               11. Twigs six-angled; usually only two bud scales visible, these in front and back; never fruiting. —**V. Opulus roseum* L.
               11. Twigs slightly if at all angled; more than two bud scales visible, the first pair lateral; fruit often present.
                  12. Bark of older twigs exfoliating. —?**V. molle* Michx.
                  12. Bark of older twigs not exfoliating. —*V. dentatum* L.

SYMPHORICARPUS L. Wolfberry; Coralberry; Snowberry; Buckbrush

Habit—Small, deciduous shrubs. **Twigs**—Slender. Lenticels inconspicuous. Pith brown, spongy or excavated. **Leaf Scars**—Opposite, small, half-round to crescent-shaped, raised as a shelf for the bud. Bundle scars none, but opposite leaf scars connected by a transverse

ridge. **Buds**—Small, solitary or collateral with about four to eight keeled, four-ranked bud scales visible. **Bud Content**—Lvs. small, glabrous, vernation straight to involute. **Leaf Remnants**—Simple, entire or sinuate margins. Pinnately veined. **Fruit Remnants**—Berries borne in clusters, reddish or white.

1. Twigs glabrous; pith excavated on the older twigs. —**S. albus* Blake.
1. Twigs puberulent to pubescent; pith solid to excavated.
    2. Pith of older twigs excavated between the nodes. —*S. occidentalis* Hook.
    2. Pith of older twigs sometimes spongy but not excavated.
        3. Buds rather large, up to 2 mm. long; young twigs usually silky-shreddy; sparingly pubescent. —**S. vaccinioides* Rydb.
        3. Buds smaller, seldom over 1 mm. long; young twigs not silky-shreddy, definitely pubescent. —*S. orbiculatus* Moench.

KOLKWITZIA Graebn. Beautybush

Habit—Upright, deciduous shrub. **Twigs**—Rather slender, older twigs with shreddy bark, brown to straw-colored, short-villous. Lenticels not conspicuous. Pith whitish, moderate. **Leaf Scars**—Opposite, triangular to crescent-shaped, raised. Bundle scars three. Stipular scars none, but opposite leaf scars connected by a transverse ridge. **Buds**—Small, solitary, brown to straw-colored, short-pubescent, about six to eight bud scales visible, the first two at least keeled. **Bud Content**—Scales grade into simple, ovate, entire, pinnately veined lvs. with straight vernation. **Leaf Remnants**—Acuminate apex, entire or obscurely toothed, the petiole very short. **Fruit Remnants**—Dry, hispid achenes. —**K. amabilis* Graebn.

DIERVILLA Adans. Bush Honeysuckle

Habit—Deciduous shrubs. **Twigs**—Slender to stout, straw to brown, ridged longitudinally, some of the ridges from a point between leaf scars. Pith white, moderate to large. **Leaf Scars**—Opposite, crescent- to V-shaped, little raised. Bundle scars three. Stipular scars none, but opposite leaf scars connected by a transverse ridge. **Buds**—Solitary or sometimes superimposed, brownish to gray, with about eight to ten keeled, acute to attenuated bud scales visible, these opposite and in four ranks. **Bud Content**—Scales grade into simple, rather long lvs. the vernation becoming involute. **Leaf Remnants**—Pinnately veined, serrated. **Fruit Remnants**—Long capsule with sepal remains usually at top.

This is a well marked genus in its winter characters, but the species are almost impossible to distinguish in any condition. However, our native species *D. Lonicera* Mill. differs from the cultivated forms very

clearly by not having hairs on the much fainter longitudinally-running ridges. The cultivated forms have been collectively called *D. hybrida* Voss.

LONICERA L. Honeysuckle

Habit—Upright shrubs or twiners, deciduous or exceptionally partly evergreen. **Twigs**—Sometimes ridged or angled. Pith moderate to large, white or brown, continuous or excavated between the nodes. **Leaf Scars**—Opposite, triangular, crescentic to half-round, somewhat raised. Bundle scars three. Stipular scars none, but opposite leaf scars connected by transverse ridges. **Buds**—Often superimposed, the lower one larger, with two to many opposite four-ranked bud scales visible. **Bud Content**—Lvs. simple, entire, pinnately veined, vernation straight. **Leaf Remnants**—Entire, sometimes connate. **Fruit Remnants**—A black or red berry.

1. Vines, with climbing stems.
   2. Stems pubescent, light brown; none of lvs. connate, hence none of leaf scars meeting and continuous with the opposite one. —**L. japonica* Thunb.
   2. Stems glabrous, straw-colored; upper lvs. connate, hence upper leaf scars as a ring encircling the twig.
      3. Fruit clusters in rather remote whorls; bud scales close; lvs. white to somewhat glaucous beneath. *L. sempervirens* L.
      3. Fruit clusters in crowded whorls; bud scales usually somewhat spreading at tip; lvs. heavily glaucous beneath.
         4. Remnants of connate lvs. rhombic or oblong, acute, not glaucous above; usually less than ten bud scales visible. —*L. dioica* L.
         4. Connate lvs. orbicular, obtuse or emarginate, glaucous on both sides; often over ten bud scales visible. —*L. prolifera* Rehd.
1. Upright shrubs, not climbing.
   5. Pith white, spongy but not excavated between the nodes. —**L. fragrantissima* Lindl. & Paxt.
   5. Pith brownish, excavated between the nodes.
      6. Buds fusiform or lancoid, often over 6 mm long —**L. Xylosteum* L.
      6. Buds conical to ovoid, shorter.
         7. Buds not strongly divergent, forming less than a forty-five degree angle to the twig, short ovoid to conical. —**L. Ruprechtiana* Reg.
         7. Buds more strongly divergent, ovoid.
            8. Twigs glabrous; our most common species. —**L. tatarica* L.
            8. Twigs pubescent, at least near the ends; rarely planted here.
               9. Bark of older twigs peeling in scales or plates, not silky shreddy; fruit pedicel long, over 6 mm. —**L. Maackii* Maxim.
               9. Bark of older twigs becoming silky shreddy; fruit pedicels shorter.

10. **Buds definitely pubescent; twigs pubescent and shredding very soon; lenticels gray. —****L. Korolkowii*** **Stapf.**
10. **Buds glabrous; twigs slightly pubescent near the end, shredding only on older twigs; lenticels dark. —****L. Morrowii*** **A. Gray.**

Two other species have been reported as native to the state, ***L. glaucescens*** Rydb. and *L. canadensis* Marsh., but if they are present here they must be very rare and local.

Family COMPOSITÆ

ARTEMISIA L. Worm-wood; Sage-brush

Habit—Deciduous sub-shrubs with an aromatic odor. **Twigs**—Moderate to stout, puberulent with small whitish dots. Lenticels inconspicuous. Pith white, moderate. **Leaf Scars**—Alt., more than two-ranked, wide V- or U-shaped. Bundle scars three. Stipular scars none. **Buds**—Solitary, pubescent, ovoid, obtuse, bud scales often numerous, keeled. **Bud Content**—Inner scales grade into lvs. which are flat at base and lobed or dissected. **Leaf Remnants**—Often present in winter, twice pinnate and finely dissected, margins entire. **Fruit Remnants**—Achenes borne in heads, no pappus. —**A. Abrotanum* L.

In addition to this cultivated species, a native one, *A. frigida* Willd. is known as rare locally in Monona and Lyon counties in northwestern Iowa. It has not been found in the course of the present study.

NOTES ON THE GENUS KEY

1. Often the pairs of leaf scars are not exactly opposite each other, but they can still be recognized as members of a pair. Sometimes the leaf scars of alternate-leaved twigs may crowd together and resemble an opposite condition. These conditions are not generally found and specimens taken for identification should not be collected from these oddities. Figs. 1, 12.
2. Many plants are either vine-like or upright, depending on habitat, or cultural or varietal differences. If there is a question, it is best to run the specimen through both groups. Fig. 14.
3. An evergreen is here meant as a plant whose leaves remain in a normal condition over the winter, ready to begin activity in the spring. Leaves that remain on the twig in a dried condition until late in the spring, as in many of the oaks, are not considered as evergreen.
4. The longitudinally-running ridges may be on the edges of square twigs, but are usually present on round ones. They usually run down the twig from the sides or the middle of the leaf scars. Figs. 4, 9, 15, 18.
5. Spines or thorns are definitely outgrowths from the twig and are considered as modified twigs. They may be found to contain central pith in some cases. Sometimes they are the sharp ends of actual short twigs, on which may be found leaf scars and buds. Prickles are distinguished from spines by being smaller, and rather superficial so that they can be easily broken off. Figs. 2, 21.
6. The number and shape of the bundle scars is usually very constant. In some cases, however, they are variable and when such cases are known, the genus appears in more than one category; therefore, in doubtful cases it is best to try more than one path. Often the bundles scars are obscure, especially in those genera where the leaf scars are small and raised. If a dead leaf or leaf-petiole remains, pulling this off will give a fresh, unweathered leaf scar in which the bundle scars are more easily seen. A thin slice removed from the surface of the leaf scar will usually make the bundle scars more apparent. If the cut is too deep

the number may be more than at the surface of the scar. Figs. 1, 2, 10, 15, 22.

7. The pith furnishes relatively constant characters. But always examine several twigs in several places and use some of the older, more mature twigs. It is best to make at least two sections, one diagonally across the twig and one longitudinally along it. The color is sometimes uncertain in diseased twigs so that normally white pith may turn an unhealthy brown. Excavated or partitioned pith can usually be seen more definitely on the older twigs. Spongy pith is harder to see and a good plan in doubtful cases is to cut off the end of a mature twig diagonally and let it dry for fifteen or twenty minutes. Then under the hand lens the spongy character can usually be seen. Figs. 2, 8, 11, 13, 17, 20.
8. The shape of the leaf scar is usually very characteristic, but often rather hard to describe. In species where the bud is formed beneath the broad leaf scar and through development ruptures it at the top, the resulting scar may be rather U-shaped. In some cases the base of the leaf petiole is hollow in the center and the bud develops within it. This leaves a definitely horseshoe-shaped leaf scar open at the top. Figs. 1, 6, 7, 11.
9. This transverse connecting ridge is sometimes obscure, except near the end of the twig. It extends from the top of one leaf scar to the top of the opposite scar. In such cases stipular scars are rarely present. Figs. 1, 5, 9, 16, 20.
10. The size of the pith is figured somewhat in relation to its actual diameter, but mostly in comparison with the size of the twig. A pith one-half or more of the diameter of the twig would be considered large. In such a case, since the pith is not a mechanical tissue, the twig would be weak and easily broken. A pith from one-fourth to one-half of the diameter of the twig would be moderate in size while below one-fourth the pith would be definitely small. Figs. 2, 15.
11. On the leaf buds or lateral buds only two bud scales are visible. Sometimes on the terminal buds the two outer scales are parted in the middle and expose two more scales. Figs. 5, 16.
12. This bud has been compared to a flask with a swollen globose base and a long narrow neck. A dissection of the bud reveals next year's flowers in the enlarged basal end. Fig. 16.
13. The presence or absence of a true terminal bud is a constant

character but one that may cause confusion if not understood. The end of the twig often withers and drops off just above a lateral bud. Therefore, this lateral bud may appear to be a terminal bud, especially since it often becomes larger and tends to stand parallel to the twig. Close examination will show the twig end scar on the opposite side of the end bud from its own leaf scar. This branch scar is usually smaller and differs in appearance from the leaf scars. The absence of a true terminal bud is usually found in twigs with alternate, two-ranked leaf scars. Figs. 12, 23, 24.

14. These soft-wooded suffruticose plants usually die back to the roots every winter and are hardly considered truly woody. Sometimes the very young, rapidly growing shoots of woody plants may have rather soft wood; therefore, it is always advisable to collect from the older branches.

15. Superimposed buds are buds in which more than one are present at a node, one above the other. Sometimes these buds are separated from each other, but usually they are crowded. The lower or the upper one may be the larger. The smaller bud may be overlooked very easily. Figs. 10, 11, 20.

16. These tendrils come out opposite the leaf scars and may be considered as modified leaves. The adhesive discs at the tips of some of them allow the plant to climb a smooth wall. In those cases where tendrils are lacking the twisting and coiling of the twig serves to anchor and lift the plant. Fig. 14.

17. In some cases the leaf rachis remains and since it may be spiny tipped it serves as a spine after the fall of the leaflets. The scars of the leaflets will be found somewhere on such a spine and the true leaf scar will, of course, be absent. Fig. 18.

18. The grouping of trees as opposed to shrubs has a great practical value, but it sometimes causes difficulty. If the specimen is taken from a definite tree, there is little doubt, since a shrub can not be tree-like. But a seedling tree or one closely pruned back may resemble a shrub. A tree can be defined as a woody plant with one central stem of reasonable diameter, say over three inches. A plant with many smaller stems would be clearly a shrub. But a plant with several large stems growing together from the ground would still be considered a tree, and a plant with one stem less than three inches in diameter would certainly

be tree-like and might in fact be a young tree. All doubtful forms known to the writer are put in both groups.

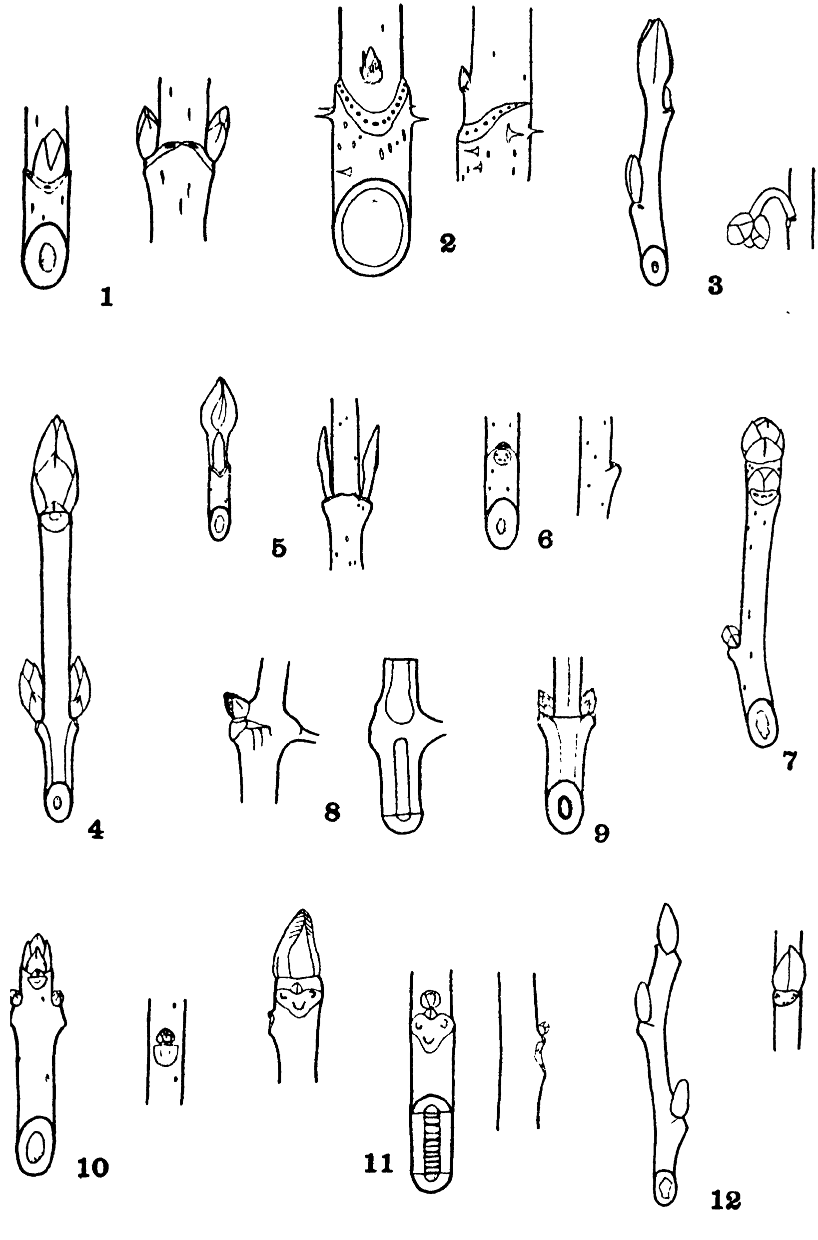
19. These short wart-like twigs are obtuse from the blunt terminal bud, and leaf scars without accompanying buds are closely crowded on them. These twigs increase in length every year and are, therefore, longer on the older twigs. Many plants, like our common apple, have short spur-like twigs, but in these the leaf scars are not densely crowded, and some of them have buds above them.
20. Buds may be partly or completely concealed by the leaf scar or the surface of the twig. In some cases the bud is so short and flattened from the end that it appears concealed. Splitting the bud longitudinally into the twig or leaf scar and removing one-half of it with part of the base beneath will give a good idea of how much of the bud is really concealed. Fig. 6.
21. A slender twig may be regarded as one with an average diameter of less than 3 mm. A moderately-sized twig ranges between 3 mm. and 6 mm., while above 6 mm. would be large or stout twigs. The twig size can be of great value but is very variable in certain limits. Always avoid basal, suckering shoots as they are usually greatly enlarged.
22. The stipule in such cases is a bud scale and when it falls it leaves a narrow ring which extends from the side of a leaf scar clear around the twig to the other side of the same scar. Fig. 19.
23. Buds are called naked when no definite bud scales are present, and the outer enveloping structures are no different than the leaves within. In practically all such cases the bud is densely hairy.
24. In a two-ranked twig the buds and the leaf scars are arranged rather roughly in two rows at the sides of the twigs. Sometimes on sprouts or on twisted twigs this two-ranked condition may be obscure. It is best to examine a mature but fairly elongated shoot and remember that this two-ranked condition need not be absolutely exact. Fig. 12.
25. In some plants the leaf scars and their accompanying buds tend to crowd out near the end of the twig. In such cases some of the lateral buds often project out farther than the terminal bud. Usually at least three leaf scars are crowded out in this manner. Basal shoots may not show this.

26. This sticky sap may harden on the cut twig-ends in time and a fresh cut should be made in testing for it.
27. The stipular scars are reasonably constant, but they are often very small and apt to escape a casual examination. They are found at the upper side of the leaf scars. Sometimes the whole or part of the stipule remains. Figs. 3, 8, 12, 14, 15, 18, 19, 22.
28. A leaf includes all that part from the tip to the bud in the axil. A simple leaf is one with its blade definitely in one piece, no matter how deeply lobed. Leaflets of a compound leaf may sometimes be confused and considered as leaves, but a bud is never found in the axil of a leaflet. Sometimes the bud is concealed in the base of the petiole.

EXPLANATION OF PLATE I

1. *Acer campestre*—Pith moderate, continuous. Lenticels rather prominent. Leaf scars opposite, V-shaped, almost meeting. Bud scales somewhat keeled.
2. *Aralia spinosa*—Twigs large, with large prickles. Pith very large. Lenticels prominent. Leaf scars narrowly U-shaped, with numerous bundle scars. Bud remote from the leaf scar.
3. *Hamamelis vernalis*—Pith small. Leaf scars about two-ranked. Stipular scars small. Buds often with two stipules simulating bud scales, otherwise naked. Incipient flowers present.
4. *Evonymus europaea*—Pith small to moderate. Leaf scars opposite, half round. Bud scales opposite, somewhat keeled.
5. *Cornus alba sibirica*—Pith moderate. Leaf scars narrowly V-shaped, opposite ones connected by a transverse ridge. Buds often stalked, the first two scales the length of the bud.
6. *Rhus trilobata*—Pith small to moderate. Leaf scars round, with about five bundle scars. Buds partly concealed by the leaf scar.
7. *Crataegus pinnatifida*—Pith moderate to large, rather irregular in section. Leaf scars reniform to crescent-shaped Bud scales somewhat keeled.
8. *Vitis Lecontiana*—Pith with a firm diaphragm at the node. Tendrils present.
9. *Symphoricarpus occidentalis*—Pith excavated. Twig with longitudinal ridges. Leaf scars definitely raised.
10. *Chionanthus virginica*—Pith moderate to large. Leaf scars half round, the bundle scars as a U-shaped line.
11. *Juglans regia*—Pith chambered. Leaf scars heart-shaped. Buds superimposed.
12. *Castanea mollissima*—Pith moderate to large, five pointed in section. Leaf scars two-ranked. Stipular scars narrow.

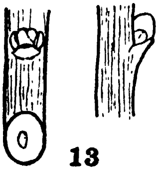
PLATE I



EXPLANATION OF PLATE II

13. *Tamarix odessana*—Pith not central, small. Leaf scars not evident, a part of the leaf base remaining.
14. *Parthenocissus quinquifolia*—Tendrils with adhesive terminal discs. Stipular scars long and narrow.
15. *Caragana frutex*—Pith small. Twig longitudinally ridged. Leaf scars raised. Stipules remaining.
16. *Viburnum prunifolium*—Leaf scars narrow V-shaped. Lateral buds with two scales visible. Terminal bud flask-shaped.
17. *Alnus glutinosa*—Pith triangular in section. Leaf scars reniform to half round. Buds stalked, about three equal scales visible.
18. *Caragana aurantiaca*—Pith small to moderate. Twigs ridged. Leaf scars raised. Stipules present. Leaf rachis a weak spine.
19. *Magnolia Fraseri*—Twigs very stout. Stipular scars as a ring encircling the twig. Bud scales of two connate stipules with a scar at the back.
20. *Lonicera Xylosteum*—Pith excavated. Buds superimposed, the lower larger.
21. *Acanthopanax Sieboldianus*—Pith moderate. Lenticels rather prominent. A spine below the leaf scar. Leaf scars U-shaped.
22. *Morus alba*—Pith moderate. Leaf scars half round, the bundle scars many and scattered.
23. *Prunus Armeniaca*—Terminal bud lacking, the laterals often collaterally multiple.
24. *Salix caprea*—Terminal bud lacking. Only one visible bud scale.

PLATE II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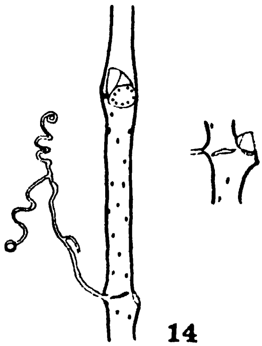
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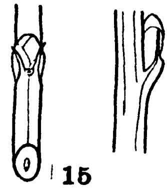
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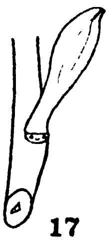
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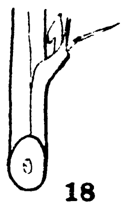
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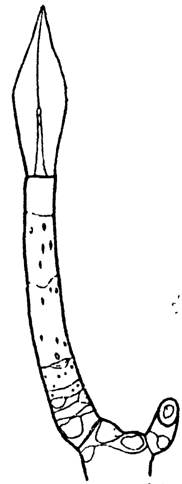
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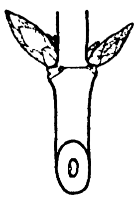
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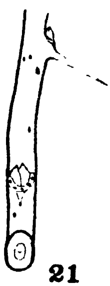
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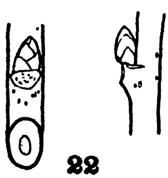
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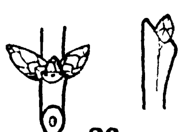
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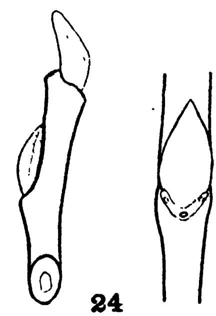
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A METHOD FOR THE MEASUREMENT OF THE INTERNAL EXPOSED SURFACE OF FOLIAGE LEAVES

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While certain authors have pointed out the probable importance of the surface exposed along intercellular spaces of leaves, no published paper seems to have dealt with the measurement of these areas. The obvious significance of this interior surface in relation to the leaf's activities seemed to warrant an attempt at its measurement. Though it was recognized that variations in structure would lessen the value of such findings, a method of procedure has been developed whereby helpful data may be secured.

The leaves of selected Iowa mesophytes were first studied and subsequently certain xeromorphic forms were surveyed for comparison. This introductory paper, however, is offered primarily to present a statement of the method employed in the measurement of a foliage leaf possessing both palisade and spongy mesophyll.

From small rectangles of leaves embedded in paraffin, transverse and tangential* sections were cut, usually ten or twelve microns thick, and stained with Delafield's haematoxylin and safranin. From these sections sample areas (3,600 μ^2) lying between veins were selected for measurement. Camera lucida drawings of the several cell layers were used where direct measurement could not be undertaken. Drawings were generally made with 10x ocular and 90x objective though occasionally the 40x objective was used where the cells were large.

A. MEASUREMENT OF THE MESOMORPHIC LEAF

Computation of the ratio, R, of the internal exposed surface to the external exposed surface of a leaf having both palisade and spongy mesophyll, may be calculated by substituting in the formula,

$$R = \frac{\Sigma(ab \ldots a_n b_n) + 1(cd + 2\frac{ef}{g}) + \frac{hi}{j},}{2k}$$

the values obtained in each of the measurements designated by letters as outlined below.

*Section parallel to flat surface of leaf (1, 2).

The Palisade

1. The average length of ten cells in the upper palisade layer was determined by direct microscopic measurement from transverse sections and $= a$, (Plate III, fig. 1).

2. Areas were selected* from the tangential section, showing the palisade cells in cross section, and a camera lucida drawing made of each sample. The total length of the palisade cell walls exposed against the intercellular space was found for each sample area by running over the lines representing exposed walls with a Keuffel and Esser No. 1692 chartometer. The average per sample of such lengths $= b$, (Plate III, fig. 2).

3. The measurements as in a were repeated for the second palisade layer and $= a_1$, (Plate III, fig. 1).

4. The measurements as in b were repeated on the drawings (tangential) of the second palisade layer and $= b_1$, (Plate III, fig. 3).

The Spongy Mesophyll

(Horizontally Exposed Surface)

1. Camera lucida drawings were made showing the cell walls of selected areas of the spongy mesophyll seen in the transverse section of the leaf. Each drawing was a sample area which included a full zone of spongy mesophyll from palisade to lower epidermis, and had a width of 60 μ. The total length of all completely exposed walls per cell making an angle not greater than 45° with the vertical was found by running over such portions of the lines with the chartometer. The total number of these vertically inclined cell walls thus measured in each sample was counted and the average length of the curved vertically exposed wall per spongy mesophyll cell $= c$, (Plate III, fig. 4).

2. Camera lucida drawings of the spongy mesophyll as seen in the tangential section were made and the total length of the exposed cell walls in each sample was measured with the chartometer and an average of the wall lengths exposed per sample $= d$, (Plate III, fig. 5).

(Dorsi-ventral Exposed Surface)

1. The area of the cells outlined in the sample drawing for d (tangential section of sponge) was found by planimeter (3),

*Five sample drawings were made wherever sampling was done by drawing.

(Keuffel and Esser planimeter No. 4238) and the average area per sample = e, (Plate III, fig. 5).

2. From the drawings for c the length of the walls *exposed* along intercellular space and making an angle greater than 45° with the vertical was measured with the chartometer. The total length of these walls for all the samples = f, (Plate III, fig. 4).*

3. From the drawings used for c the total length of walls (*exposed* and *non-exposed*) which made an angle with the vertical of greater than 45° was measured with the chartometer.* This value = g, (Plate III, fig. 4).

From the drawings used for c the average number of layers of cells which composed the spongy mesophyll was determined and that number = l, (Plate III, fig. 4).

The Inner Epidermis Wall

1. The area of the intercellular space per sample was found by subtracting the area e from the sample area (3,600 μ^2). This represented part of the area of the lower epidermis exposed inwardly against the intercellular spaces and = h, (Plate III, fig. 5).

2. From the drawings used for c the length of inner walls of the lower epidermis cells in each sample area was measured with the chartometer. The average of the total inner wall per sample was found and this number = i, (Plate III, fig. 4).

3. The length of the side of the sample area = $j = \sqrt{k}$

The External Surface

A sample area measured on the surface of the leaf = k, (k = 3,600 μ^2).

Results

Application of this method to a number of selected leaves gave for R values ranging from 7.8 to 31.3 as recently published (4).

Discussion of Method

Inasmuch as the above method is based upon drawings of leaf material which has been treated with histological reagents, sectioned, and stained, this may have caused alteration of the walls of the living cells. Tests with free hand sections of living leaves were used to determine the effects of commonly used killing reagents upon the cell wall. However, careful measurements before, during,

*When part of the lower wall of a cell was also part of the upper boundary of the cell below it, both walls were included in the total though they appeared as a single line in the drawing. If the same number of samples are not measured in f and g averages must be used instead of totals.

and after treatment showed neither extension nor shrinkage of the cell wall, though the protoplasts were altered by some treatments (5).

Accuracy is further dependent upon the histological technique used in making the slides. Poorly sectioned material in which the connections between cells are broken will result in great inaccuracies of measurement. Vigorous movements of the slide in liquid reagents after the paraffin has been dissolved tend to wash unanchored cells out of the sections. Also the cell walls must be well stained, otherwise the thin line of wall may be obscured by heavily stained chloroplasts or cell inclusions.

In making the camera lucida drawings, a selected section of the material was placed in focus and the drawing completed without changing the original focus. Only cell walls which lay clearly within the focal depth were drawn. Such a drawing included a section of 2 μ thickness, and overlying or underlying walls were avoided.

Accuracy of the instruments was checked against a Keuffel and Esser full divided Paragon scale, with 500 μ divisions, as a standard. For the measuring instruments used, the error varied between 0.5% and 2.5% depending upon the cell size and magnification. The largest error resulted from use of the chartometer in measuring drawings of cross sections of palisade cells. Under such conditions the error was reduced by taking readings only after the measurement of an entire sample.

Validity of this method as a whole as well as the total error due to instruments, was found by calculating the internal exposed surface of a hypothetical leaf of regular dimensions. By constructing sample sections through the leaf according to specifications and applying the method here described, accuracy of the formula was established. Since this check showed an error less than 2%, we may conclude that the method as outlined is reasonably accurate and may safely be used in leaf measurement. Relatively larger errors occur in the application of the method to the spongy mesophyll than to other leaf parts but such errors in leaves which contain a fair development of palisade are of less significance because the actual surface exposed in the sponge is small compared to that of the palisade, or in the sample volume as a whole.

If the leaves selected are sun leaves and from the upper part of the plant (2), it is probable that the ratio approaches the maximum for that species. Leaves of lower insertion will probably have

lower ratios than sun leaves of higher insertion due to the greater xeromorphy of the latter type of leaf (6). All samples should be selected from a given region of the blade as in certain species there may be progressive variation in thickness from base to apex (7).

Interrupting structures, other than veins, such as oil glands, etc., are deducted automatically when so small that they appear in the drawings. If the intrusions are very large, other methods can be worked out by the investigator to suit the situation.

B. MEASUREMENT OF STRONGLY XEROMORPHIC LEAVES

Leaves which are composed of palisade tissue only may be measured by following the simplified formula:

$$R = \frac{\Sigma(ab \ldots . a_n b_n)^*}{2k}$$

C. MEASUREMENT OF SUCCULENT LEAVES

Where the leaf is composed entirely of sponge tissue the formula is:

$$R = \frac{1(cd + 2\ \frac{ef}{g}\ ) + \frac{2\,hi}{\sqrt{k}}}{2k}$$

If there are no horizontally running intercellular spaces in the latter type of leaf the formula becomes simply:

$$R = \frac{1cd + \frac{2\,hi}{\sqrt{k}}}{2k}$$

D. SHORT METHOD FOR MESOMORPHIC LEAVES

Under certain conditions the investigator may be satisfied with approximate values for *R* and hence may prefer to use a shortened method for making a rough determination. The formula

$$R = \frac{AB + Cd + \frac{k}{1.56}L + \frac{k}{2.4}}{2k}$$

may be followed in making the measurements when A = the entire

*The exposed epidermal surfaces are too small to affect greatly the final results where thick leaves are concerned.

depth of the palisade tissue, B = the average of samples taken from the various layers of palisade and measured as in b, C = the total depth of sponge (using ocular micrometer), d = the average of samples taken as in long method, L determined by count as in long method, and k the same as in the long method. Our calculations based on the variations in nine species show that the application of the short formula to mesophytic types of leaves involves an error in the measurement of the horizontal surface of the spongy mesophyll of about 10% of the total internal surface.

E. CONCLUSIONS

Except for veins, application of the internal-external surface ratio to the entire leaf surface will readily give the internal exposed surface of the whole leaf. While deductions for veins in a given leaf would subtract considerably from the calculated total internal surface, it should be recalled that such deductions have not usually been made in the published studies on transpiration, photosynthesis and other leaf activities where external leaf surface has been used as a basis of comparison.

Inasmuch as the oxygen used in respiration, the carbon dioxide used in photosynthesis, and the water lost in transpiration must pass through the cellulose wall of the internal exposed surface and also through the cell membrane against it, it seems that the use of this internal-external surface ratio as a basis of comparing leaf activities would give more valuable results than their expression in terms of external leaf surface.

The writer wishes to thank Professor Robert B. Wylie for suggesting the problem, supplying microscope slides, and in every way assisting in this work.

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PLATE III

The figures are accurate copies of camera lucida drawings of the various tissues of a sun leaf of *Syringa vulgaris*. Sample areas indicated by the bounding lines are reduced one-half. With the exception of figure 1, the drawings are those from an actual series used in the measurement of the internal surface of a Syringa leaf and illustrate the samplings requisite for application of the method. On each drawing is indicated a single measurement of the type to be applied to the sample as a whole.

Fig. 1. Transverse section of leaf through palisade tissue.

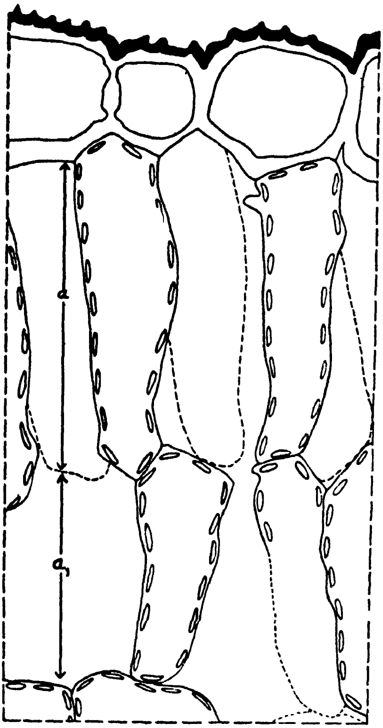
Fig. 2. Tangential section of leaf through upper layer of palisade tissue, used for measurement *b*.

Fig. 3. Tangential section through lower layer of palisade tissue.

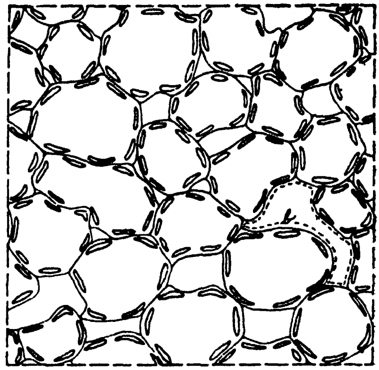
Fig. 4. Transverse section of leaf through spongy mesophyll, used for measurements *c*, *f*, *g*, *i*, and *l* (represented by numbers 1, 2, and 3).

Fig. 5. Tangential section of leaf through spongy mesophyll, used for measurements *d*, *e*, and *h*.

PLATE III



1



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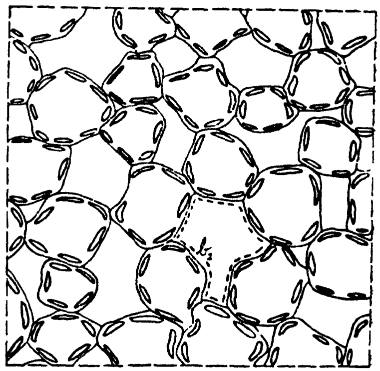

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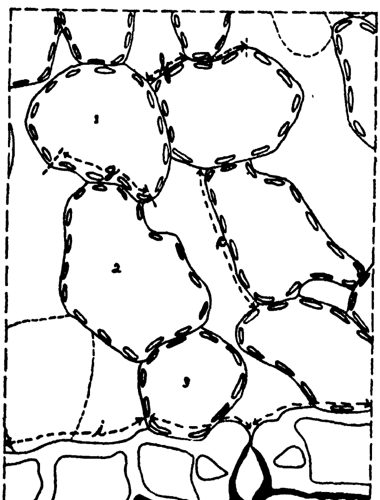

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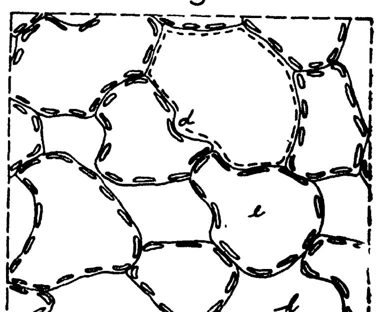
5



NOTES ON THE LIFE HISTORY OF APHANIZOMENON FLOS-AQUAE

EARL T. ROSE

With few exceptions, the lakes of Iowa are subject to seasonal growths of objectionable blue-green algae. The two species occurring most commonly are *Aphanizomenon flos-aquae* and *Microcystis aeruginosa.* While the *Microcystis* may be extremely offensive at times, the *Aphanizomenon* is usually the chief offender. With some variation due to seasonal differences, it usually becomes abundant about the first of July, appearing as small green flakes floating on or near the surface of the water. The alga reproduces with extreme rapidity and during the hot, dry periods of later summer and fall accumulates in thick mats on the surface of the water on the leeward sides of the lakes, where decomposition begins. This results in the production of an extremely offensive odor and the death of numerous fish and crustacea, partly through exhaustion of the oxygen, partly by the liberation of toxic substances released by the decomposition, as shown by Prescott. (10) It is known that these offensive growths can be controlled without injury to fish and fish-food organisms by the judicious use of copper-sulfate or chlorine, provided proper consideration is given to temperature, alkalinity of the water and other variable factors. In view of the importance of the algal species named, however, it is surprising that practically no information is available concerning their life histories. In order partially to supply this lack the following observations are reported.

COLLECTION AND CULTURE

Study of a large number of lakes in which *Aphanizomenon* is abundant suggests that the following factors favor its growth:

1. Alkalinity of the water. In all lakes in which the growth is most offensive the waters are strongly alkaline, usually ranging between pH 8 and pH 11, usually 150–300 p.p.m. alkalinity expressed as calcium carbonate.
2. Pollution. Sewage and excreta from farm animals is an important factor favoring excessive growth.
3. Shallow water. The relation here is probably one of tempera-

ture. A shallow lake becomes much warmer than a deep lake. *Aphanizomenon* and other blue-green algae are able to thrive in such warm water. Probably the most important single factor.

4. A deep layer of mud on the bottom. This favors the growth of *Aphanizomenon,* perhaps by providing a favorable place for the overwintering of the species, both as vegetative filaments and in the akinete stage.

All of these conditions occur at Silver Lake in Dickinson County. The material for study was largely secured from this lake.

Aphanizomenon seems never to have been cultured successfully. Repeated attempts to grow it in various culture solutions which have been recommended for blue-green algae, made up with distilled water and nutrient salts or filtered lake water, resulted in failure when the ordinary vegetative flakes, or filaments from these, were introduced into the culture solutions. It was therefore thought advisable to attempt to grow the species from akinetes. Akinetes are formed abundantly, and it has been assumed, although without experimental evidence, that these structures serve to initiate each new season's growth. Such an assumption is, of course, reasonable.

Some akinetes are formed during the summer, but they become abundant in late summer and fall and spore formation occurs until winter.

Silver Lake had supported an extremely abundant growth of *Aphanizomenon* during the season of 1933, and the algae were still abundant in December, when the lake was partially frozen over. In some areas the ice was colored a brilliant green by the included algae. In the open water, vigorous-looking flakes were abundant. These were collected with a plankton net and brought back to the laboratory. Examination showed that most of the filaments in these flakes contained one or more large akinetes. Where more than one akinete was present in a single filament they often occurred in pairs, a situation not heretofore reported. When either solitary or in pairs the individual akinetes were often longer than the dimensions given in the literature, 35–80 μ (Smith (11)), attaining, in some cases, 115 μ. This seems to suggest that the akinetes enlarge substantially before maturation, and that maturation does not occur until cold weather. All of the following notes are based on material collected in December, the akinetes in the summer collec-

tions, although abundant and within the range of the ordinary dimensions cited, failing completely to germinate.

All collections were kept in the cold temperature room at about 5° C in the original collection jars containing the akinetes and lake water, and removed only for obtaining material for study. No results were obtained by using methods described for germination and development of other species of blue-green algae which have been investigated (5, 6, 7, 8, 12). Petri dish and flask cultures using lake water and various recommended culture solutions were not effective; although some germination was obtained, subsequent development failed to occur.

On one occasion a small vial (10 ml. shell vial) containing many akinetes of *Aphanizomenon* was unintentionally left on the laboratory table for two days, consequently being exposed to a little direct sunlight, and room temperature. The vial was nearly full of the spore material in lake water and tightly stoppered. Upon examination it was discovered that many of the akinetes had germinated. The various stages of germination and development to be noted were taken from this and material treated in a similar manner.

SPORE GERMINATION

In view of the fact that flakes of *Aphanizomenon* are seldom, if ever, collected in early spring by the plankton net, it may be assumed that the ordinary vegetative progagation by fragmentation of the flake is not the usual method of reproduction after the winter months. When flakes are obtained in the spring they usually consist of a mass of akinetes in lateral contact with one another having but a few vegetative cells adhering. During mild winters many colonies doubtless continue their vegetative existence until the following summer.

Two methods of akinete germination have been noted and they coincide to some extent with the observations of Fritsch (4) on *Anabaena Azollae*, and with those of Spratt (12) on *Anabaena Cycadeae.*

The first method of germination, which I believe the more usual, involves a combination of two forces, first, that exerted by the swelling of the highly hydrophilic mucilaginous substance which surrounds the endospore, and second, the endospore itself divides, forming a chain of several cells. This results in the rupture of the

exospore and the release of the young sporeling. The cells of these filaments, as well as those formed by the second method, are all of the same general appearance, being broader than they are long. Such filaments would be classed as belonging to the genus *Trichodesmium*. Clusters of similar filaments are common in the early stages of development in *Aphanizomenon* (Plate IV, fig. 17), merging by gradual degrees as the filaments mature into typical vegetative *Aphanizomenon* filaments.

The second method of germination, which, judging from the material and data at hand, seems to be almost as prevalent as the first, consists of the rupturing of the wall of the exospore, and the emergence of the endospore through the rupture. The endospore, or sporeling, is in this case similar to the young sporeling described above except that division of the protoplast is not evident (Plate IV). In this method of germination, one end of the exospore is forced open by pressure exerted upon it by the expansion of the mucilaginous substance which surrounds the endospore. The presence of this mucilaginous substance may be demonstrated by staining with fast-green. The endospore is then forced from the exospore by the rapidly swelling mucilaginous material, the whole process taking approximately twenty-four hours. The protoplast then divides by the formation of septa which grow inward from the lateral walls and thus becomes a young trichome which rapidly increases in length.

There is some evidence that the trichomes of *Aphanizomenon* have two cellular investments or envelopes—an inner investment which completely encloses the protoplasts of the cells, and from which the septations arise during cell division, and an outer investment which is simply a cylindrical sheath which is derived from the inner investment (Plate IV, fig. 8). A somewhat similar account is recorded by Fritsch (4) for *Anabaena*; however, some differences may be noted. In *Anabaena* the outer investment is split into two fresh sheaths on cell division, by the development of an intercellular septum from the inner investment.

FORMATION OF THE FLAKE

One of the characteristics of the Cyanophyceae is the usual presence of a gelatinous or mucilaginous substance surrounding the filaments or cells. This characteristic is not easily observable in *Aphanizomenon,* but its habit of growth is evidence of the presence

of this cohesive material. Mature flakes usually consist of hundreds of trichomes. Flake formation is facilitated by the simultaneous germination of a group of laterally attached akinetes as a unit, the young sporelings becoming attached at the moment of their germination. This has been observed many times (Plate IV, figs. 9, 17; Plate V).

The young filaments described above under akinete germination were mostly from akinetes which had become separated from one another by shaking and handling, consequently the joining of filaments necessitated their union some time after their emergence from the exposure. The fact that many perfectly normal flakes were formed in the cultures further substantiates the existence of a cohesive substance around the filaments, and suggests that its function is to enable the filaments to adhere to each other.

HETEROCYSTS

The young sporeling, soon after having divided to form several cells, often develops a heterocyst, usually toward the middle of the trichome. The writer is not prepared to state that the heterocysts have a function in *Aphanizomenon.* From the experience with this blue-green it would seem that it is practically functionless. Observation of heterocysts from cultures and from material collected in the natural habitat have never given any evidence which might lead one to believe they might function as gonidia, as has been reported in a few isolated instances for *Anabaena*, (2, 4, 12). Heterocysts in a number of blue-greens offer a means of separation of the trichomes in order further to propagate the organisms. In *Anabaena* the breaking point of a trichome is usually between a heterocyst and a vegetative cell. This seldom occurs in *Aphanizomenon.*

The heterocyst is composed of a single cell which in its early state appears as an enlarged, rounded, vegetative cell (Plate IV, fig. 10). Here, however, the inner and outer integuments are in evidence. The protoplasm within the inner investment appears more homogeneous in substance than that of the ordinary vegetative cell. Often there are one or two small granules of cyanophycin present within the cell. A number of young heterocysts were observed which contained a large vacuole (Plate IV, fig. 11). This has not been observed in the later stages of development, and its significance is not known. As the heterocyst matures, the outer investment enlarges separating it into two distinct layers, an outer hya-

line region, and an inner region which is separated from the adjacent vegetative cells by a highly refractive granule (Plate IV, figs. 12, 13, 14, 16). In some cases the heterocysts secrete an enormous amount of mucilage (Plate IV, fig. 16). This is best observed in the living state as the usual preservatives dissolve this material.

AKINETE FORMATION

As is usually the case with organisms which form resistant resting bodies, conditions which are not conducive to continued vegetative existence favor the formation of these structures. As previously noted, akinetes (spores) are formed in abundance early in the winter, at which time collections may easily be made by means of a plankton net. In the summer the organisms often become too abundant, forming the huge mats which later decay on the surface. The conditions resulting from the decay of the algae on the surface cause akinetes to be formed to some extent in those organisms below the surface. Akinetes collected in the summer have, as previously stated, consistently failed to germinate.

The akinetes develop from single cells located near the mid-region of the trichome. This is advantageous due to the fact that the akinetes in the flake will all be united by their lateral walls in a compact bundle. After the decomposition of their adhering vegetative cells, which have previously buoyed up the plant mass, the akinetes sink to the bottom. The simultaneous germination of the akinetes in a bundle facilitates the direct formation of a new flake.

The steps involved in the formation of the akinetes are shown on Plate IV, figs. 2, 3, 4, and 5. Such transformation of a single vegetative cell involves the accumulation of a large amount of reserve food material, thickening of the outer wall, and elongation of the cell. The reserve food materials according to Baumgärtel (1) and Poljansky & Petruchevsky (9) consist of a number of indefinite substances of a glycogen and protein nature. The mature akinete is connected with the vegetative cells at either end by a highly refractive substance which consists apparently of the same material as that which composes the large granules which become so abundant in the akinetes (Plate IV, fig. 5). These granules are the so-called cyanophycin bodies.

DISCUSSION

The foregoing account includes in the main the complete life cycle of *Aphanizomenon flos-aquae*. The cytological details are pre-

sumably similar to those of other spore-forming blue-green algae. Preparations stained with iron alum haemotoxylin show the chromatin condition to be similar to other closely related forms (Plate IV, fig. 15).

A temperature of 8° C. is the minimum at which spore germination may take place. Light is not essential for germination; flake formation, however, did not take place unless the organisms were placed in the light. Temperatures ranging from 15° to 22° C. were found to be best for continued growth and reproduction in culture. The source of light in most studies was a 100 watt lamp placed over the culture chamber. The culture chamber was iced to keep the temperature low, consequently some variation was inevitable.

Species-pure cultures of this organism are easily procured by germinating a mass of spore material in the small vials. The filaments so formed rise to the top of the vial and may readily be removed by means of a pipette to another vial. This method was found to be rapid and effective. The necessity for such a procedure is obvious, since many other organisms are present which rapidly contaminate the culture. Bacteriologically pure cultures were attempted many times, using agar plates and other methods described, but without success.

As noted elsewhere, the various culture solutions recommended for the growth of blue-green algae were of little value in culturing *Aphanizomenon.* Since the use of small shell-vials as culture containers and the obtaining of good growths using redistilled water as a medium, many of the recommended solutions are being tried again.

This study was made possible by a grant from the State Fish and Game Department and State Board of Conservation of Iowa. The laboratory work was done in the Botany Department of the State University of Iowa, under the supervision of Dr. G. W. Martin.

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PLATE IV

Fig. 1. Small flake developed from akinetes in culture. x 362.

Figs. 2, 3, 4, 5. Development of the akinete. Figs. 2, 3, 4 x 850, Fig. 5 x 1260.

Fig. 6. Double akinete. x 650.

Fig. 7. Germination of akinete, showing large cyanophycin granules. x 1260.

Fig. 8. Germination of akinete. Stained in safranin, showing outer investment of protoplast. x 850.

Fig. 9. Young trichomes from 24 hour culture. x 850.

Figs. 10–16. Development of heterocyst. Fig. 15 stained with iron-alum-haemotoxylin showing chromatin in vegetative cells. x 850.

Fig. 17. Portion of flake from a three-day culture, showing the *Trichodesmium*-like cells. x 850.

PLATE IV

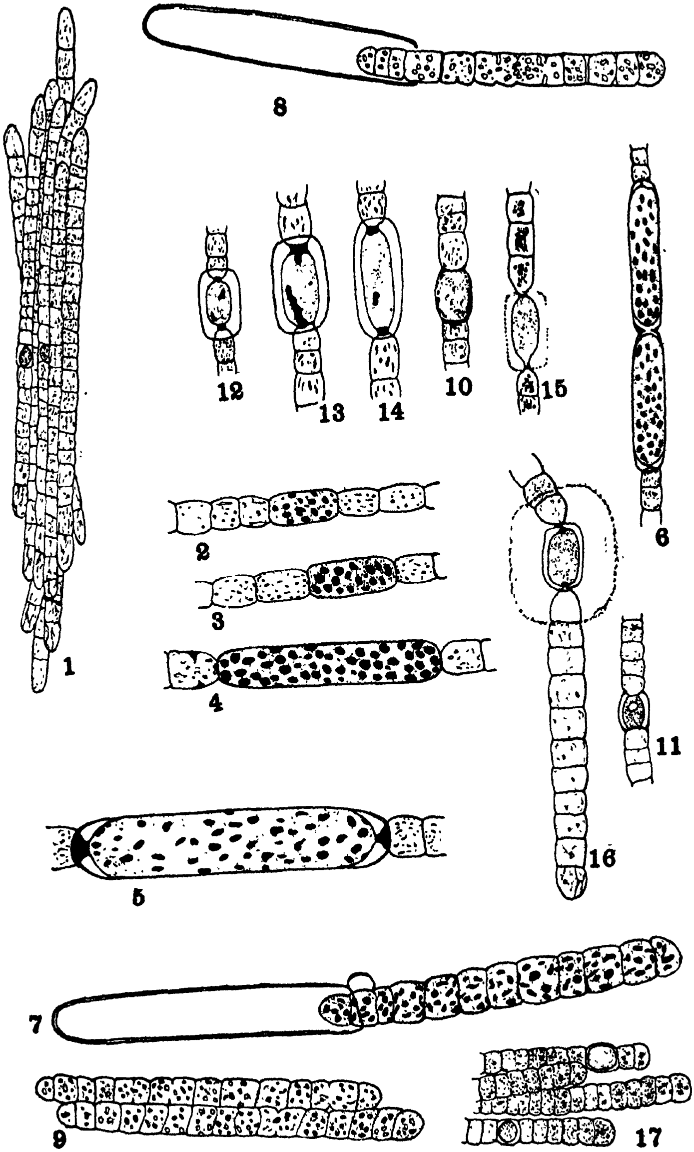

PLATE V

Fig. 18. Photomicrograph of most common method of akinete germination, in which the sporeling is differentiated into cells at time of germination. x 450.

Fig. 19. Photomicrograph of akinete germination in which the sporeling is undifferentiated. The large bodies within the protoplast are cyanophycin granules. x 1350.

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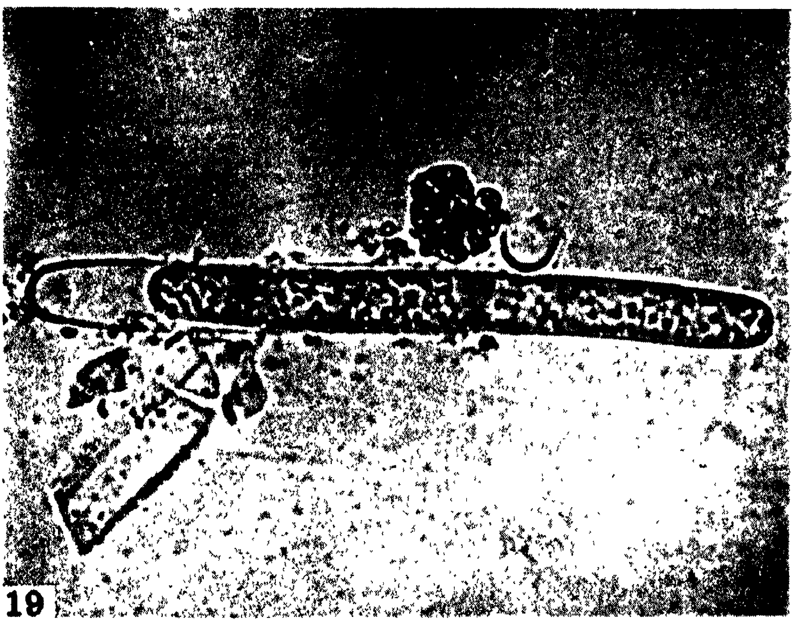


19

THE GENUS STYPELLA

G. W. Martin

Stypella was established in 1895 by A. Möller (Protobasidiomyceten, 75) to accommodate two species of tremellaceous fungi collected on rotten wood in Brazil. Möller regarded the genus as sufficiently distinct to warrant its segregation in a separate subfamily, the Stypelleae. Neither of Möller's species was again reported until 1930, when, believing I had rediscovered one of them, *S. minor*, in Iowa, I published a brief reference to it under that name (Proc. Ia. Ac. 36: 128). More recently Linder has described from Missouri as *Tremella gangliformis* (Mycologia 25: 105. 1933) what is certainly the same fungus as that reported from Iowa. This raises the question as to whether the original reference of the Iowa material was justified, and, if not, just what Möller's genus represents. Whether Möller's types are still in existence, and if so, where they are deposited, I have been unable to learn. The descriptions, however, are ample, and the illustrations clear, and it should be possible, with their aid, to gain a reasonably satisfactory idea of the character of the genus.

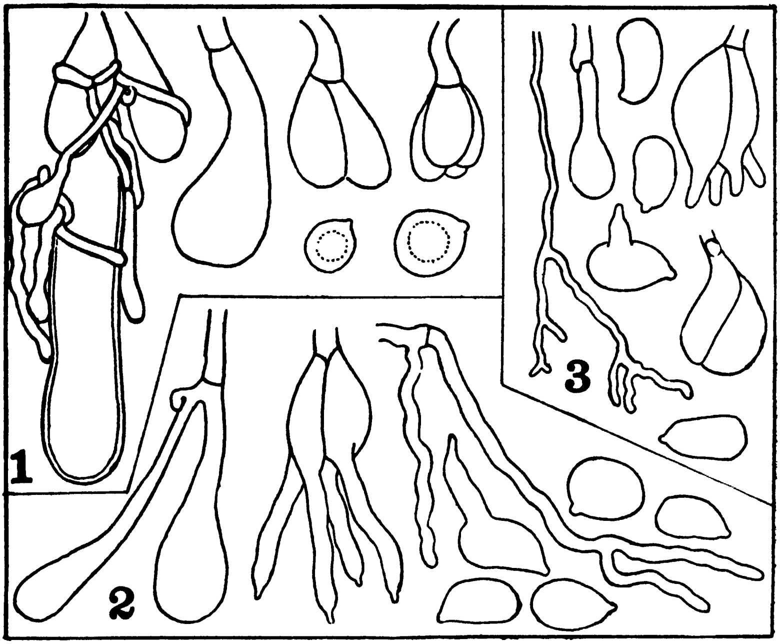
In the last pages of his volume Möller summarizes the less formal discussion of the earlier pages. On p. 166 he says of the Stypelleae: "Entsprechen den Stypinelleen unter den Auriculariaceen. Basidien frei und einzeln an den Myzelfäden, ohne Fruchtkörperbildung." Of the single genus *Stypella* he merely notes: characters of the group. Now *Stypinella* Schroeter, which is a synonym of *Helicobasidium* Patouillard, is, it is generally conceded, characterized by a soft, floccose, non-gelatinous, "tow-like" habit, with the basidia borne singly and at various heights on the hyphae; that is to say, a hymenium is quite definitely lacking. This comparison with *Stypinella* seems to be responsible for the conception of *Stypella* which has been presented in most of the later systematic works which have referred to that genus. Thus Lindau, in the first edition of Engler and Prantl, speaks of it as "wergartig," and this characterization is copied by Killermann in the second edition. Saccardo and Sydow (Syll. fung. 14: 246) merely paraphrase Möller's statement that it is like *Stypinella* but with globose, tremellaceous basidia. Clements, and Clements and Shear say "pileus

byssoid." On the other hand, von Höhnel (Ann. Myc. 2: 749. 1915) suggests that the two species represent early stages of an *Exidiopsis* and a *Heterochaete* respectively, and Burt (Ann. Mo. Bot. Gard. 2: 749. 1915) regards the genus as included in *Sebacina*. Neuhoff, (Bot. Arch. 8: 287. 1924) likewise, regards *Stypella* as a subgenus of *Sebacina* and states that *Exidiopsis* is a synonym of that genus. There is no reason to suppose that any of the last-named authors ever saw Möller's specimens, but they had evidently read his descriptions carefully. In view of the close approach of certain species of *Sebacina* to the fungi under discussion, this disposition of the genus is not unreasonable.

Möller specifically states that there is no fructification, but both by description and drawing he makes it clear that this is merely a matter of definition. He regards the genus as a fulfillment of Brefeld's prophecy (Untersuchungen 7: 24, footnote) that genera would be discovered among the Heterobasidiomycetes corresponding to what he regarded as the Tomentelleae of the Homobasidiomycetes, that is, with free basidia not united into a hymenium. The fact that Brefeld's conception of what constituted a hymenium was inadequate, and that it was adopted by Möller and applied by him to the condition existing in *Stypella*, is important in this connection. The pustular aggregations of basidia-bearing hyphae, massed within a restricted area and connected by a network, more or less developed, of subicular hyphae, constitute a fructification exactly comparable with that found in certain of the more tenuous forms of *Grandinia*, *Tomentella* and *Corticium*.

The references to the tow-like or byssoid character of the fungus are obviously due, not to Möller's description, but to his comparison with *Stypinella*. True, when the subicular hyphae are well developed (see Plate VI, fig. 4a), these terms are not inapplicable to the dry fructification, but they are much less applicable to it when it is soaked. It is clear that Möller regarded *Stypinella* as the auriculariaceous equivalent of *Tomentella*, and *Stypella* as occupying the same position among the Tremellineae. The emphasis is upon the rather loose and open character of the fructification, and not at all upon a tow-like or byssoid texture.

These contentions are supported by the descriptions of the species. *Stypella papillata*, to be regarded as the type, is made up, according to Möller, of small, irregularly circumscribed areas scarcely ½ mm. in breadth, grouped irregularly into masses up to



EXPLANATION OF TEXT FIGURE

All drawings made with aid of camera lucida, and all reduced in reproduction to x 1500, except upper left hand drawing in Fig. 1, which is reduced to x 683.

Fig. 1. *Stypella papillata.* Cluster of three gloeocystidia, two young and one older, with hyphae bearing probasidia encircling them; also young stages of three basidia, and two spores. Fig. 2. *Stypella minor.* Two probasidia, one nearly mature basidium, paraphysoid and five spores, one germinating. Fig. 3. *Tremella Grilletii.* Paraphysoid, three stages in development of basidia and four spores, one germinating.

1½ cm. in length, the entire group with a smooth, glassy appearance when moist, and papillate under a lens, completely disappearing to the naked eye when dry. Microscopic examination reveals that the papillae are connected by a loose, irregular network of slender hyphae, apparently imbedded in a thin jelly.

Two collections made at Highlands, N. C., during the August, 1933, foray of the Mycological Society of America, are referred to this species. They were both growing on very rotten coniferous wood lying on the ground. The fungus occurred in the form of scattered, irregular patches, the largest of which was about 2½ cm.

in greatest extent. Under the lens the papillae appeared as short, blunt spines, giving the fungus the aspect of a *Protodontia* with very small spines. Microscopic examination showed, however, that the supposed spines were composed of from one to a dozen of the characteristic gloeocystidia, with the mycelium bearing the basidia loosely grouped around them, and the entire cluster connected by a delicate system of hyphal threads. While the more advanced portions of the fructifications were more spinose than Möller's description would suggest, the transition from the spinose tubercles at the heart of the cluster to the flat, cushion-like pustules at the margin was entirely gradual. Examination of such younger tubercles, very lightly crushed under a cover slip, shows that the gloeocystidia first drop below the general level of the substratum and that later the mycelium bearing the basidia grows over and amongst them (Text Fig. 1). The gloeocystidia are rather irregular in size and shape, but mostly 70–150 x 10–16 μ, the longer ones being more slender. Möller says up to 200μ in length and 10μ in thickness. In view of the very great variability of this character in the tremellaceous fungi possessing gloeocystidia, such difference cannot be regarded as significant. The probasidia are pyriform to subglobose, mostly 7–8μ in diameter. Möller says 10μ, but the two basidia shown in his illustration are 6μ and 8μ broad respectively, if checked by the magnification given. The spores are globose, 4.5–6μ in diameter. Möller says "rundlich, 4μ," but illustrates two spores, both still attached to sterigmata, one, apparently about mature, 6 x 4.5μ, the other, obviously immature, 4.5 x 3μ.

It cannot be maintained that the identity of the Highlands collections with *S. papillata* is positively established. Möller's description and illustration give a vivid picture of the fungus he had before him. The differences between his account and the characters of the North Carolina material are such as might readily be explained on the basis of the known wide range of variability in fungi belonging to this group. It seems better, therefore, to use Möller's name for these collections rather than to apply a new one which would in all probability have to be relegated to synonymy.

As stated above, von Höhnel suggested that *S. papillata* (he says *S. minor*, but the context makes it clear that this is merely a slip) might represent an undeveloped *Heterochaete*. But the resemblance between *Heterochaete* and *S. papillata* is confined to the gloeocystidia. In every other respect *S. papillata* is quite distinct

from any known *Heterochaete,* and, as has been pointed out repeatedly by Burt and again by Rogers (see Ann. Myc. 31: 181. 1933), this character alone is not of generic value.

Möller's second species, *S. minor,* is described as outwardly indistinguishable from *S. papillata,* appearing as a thin, gray pubescence, irregularly circumscribed, composed of a loose tangle of delicate mycelium bearing tufts of hyphae which are responsible for the papillate surface. The distinctions between the two species are based mainly upon the presence or absence of gloeocystidia, and the size and shape of the spores. Gloeocystidia are lacking in *S minor,* their place being taken by slender, branched hyphae, about 3μ in diameter, which form the centers of the papillae, and which may be referred to as paraphysoids. The paraphysoids in our specimens are more slender, mostly under 2μ, but thicker, and more irregular and tortuous than those of the forms referred to *Tremella Grilletii.* Möller gives the breadth of the basidia as 4–5μ, but this must be inaccurate, since a subglobose basidium of this diameter could not produce four spores 6 x 3μ. If a calculation is made on the basis of the magnification given for his drawing, the diameter of the basidia is approximately 7–9μ.

The fungus which I have referred to *S. minor* is common in Iowa and Missouri, and is the same as *Tremella gangliformis* Linder (Text Fig. 2; Plate VI, Figs. 1–4). It usually occurs in rather small patches, but occasionally forms moderately conspicuous fructifications several centimeters in extent. It varies all the way from small clusters of almost completely separated papillae connected merely by an extremely tenuous subiculum (Plate VI, Fig. 3) to phases in which the papillae are so densely massed and anastomosed as to form an almost continuous gelatinous network, never, however, losing the papillate character which is the expression of the tufted habit of the fructification. Such fruitings, when dry, are easily visible to the naked eye, and do exhibit, under a lens, a somewhat byssoid appearance (Plate VI, Fig. 4a).

The probasidia are 7–8(–9)μ in width, and after division into two or four, rarely three cells, produce epibasidia of the same thickness as the paraphysoids and mostly 10–15μ long. The longest epibasidium observed, 22μ, was far short of the dimensions given by Linder, 36–40μ, but he figures a basidium producing spores, hence mature, in which the epibasidia are 10μ long, which is in agreement with our material. The spore-size cited in the original description

was 6 x 3μ. Linder describes the spores of *T. gangliformis* as globose to ovoid, 5.5–6 x 4–5μ. My measurements show a considerable range both of size and shape, but in general the shape is oval or short cylindrical and suballantoid, 6–9 x 3–5μ.

A third species, obviously very close to *Stypella minor,* is *Tremella Grilletii* Boud., Bull. Soc. Bot. Fr. 32: 284. 1885. This is beautifully characterized in the original description, of which the following is a translation: Very small, scarcely exceeding 0.3–0.4 mm. in diameter, rounded or sublenticular, pale ashy lilac or subhyaline, in dense clusters, forming cinereus or lilaceous blotches 1–2 cm. in diameter; hymenium appearing very finely papillate under the microscope, and pruinose from the presence of spores; basidia rounded, longitudinally septate, with four flexuous and elongated sterigmata; spores hyaline, oblong, a trifle curved, obtuse and rounded at the tip, obliquely apiculate at the base, which is a trifle narrower, the contents finely granular with a vacuole in the midst, often located near the wall, 8–10 x 3–5 μ. . . . It forms small disks of a pale violaceous gray, and has exactly the appearance of certain discomycetes of the genus Ascophanus.

Bourdot and Galzin list the species as not rare. They give the spore dimensions as 6–10 x 3–5μ, and add measurements of basidia, 8–12 x 6–10μ, and epibasidia, 15–20 x 2μ. They also note the paraphysoidal branches, which are described as simple or forked. In our material these structures are always forked, as shown in text figure 3.

The species is not a *Tremella* as that genus is ordinarily understood at present. Bourdot and Galzin suggest *Exidia,* where its spores would seem to place it. They also note that the pustules may become confluent so as to resemble certain forms of *Sebacina fugacissima.* It is certainly very close to *Stypella minor,* and may not be specifically distinct, in which case the specific name has priority. We have a collection from Iowa which is tentatively referred to Boudier's species, and which differs from *S. minor* as here defined in the slightly larger size and remarkable regularity of the pustules, which are connected by an extremely tenuous subiculum, in the distinctly lilaceous color, in the slightly longer, narrower and more curved spores, 6–8 x 3.5–4μ, and in the more slender paraphysoids, 1–1.5μ in thickness. In the Tremellaceae, none of these distinctions, taken alone, is of specific significance, but taken together, they may justify recognition of the species. Certainly, it must eventually be

included in the same genus as *Stypella minor,* if not merged with that species.

The taxonomic disposition of these species offers considerable difficulty. They do not fit naturally into *Tremella, Exidia* or *Heterochaete.* They are unquestionably closer to the thin, gelatinous, effused species of *Sebacina* (including *Bourdotia*) as that genus is now recognized. But the type species of Sebacina is *S. incrustans* (Pers.) Tul., a familiar, coriaceous, often subpileate fungus which it is difficult to believe is congeneric with these delicate forms. *Sebacina* is in need of thorough revision, a task which will demand long and careful study. But when this has been accomplished, it must include *S. incrustans* and all similar forms, and it is my belief that the delicate, gelatinous forms originating as distinct pustules will have to be excluded. If, however, Möller's characterization of Stypella is studied in the light of the clear species descriptions and the figures, we have a satisfactory genus to receive them. I therefore venture to present the following emendation of Möller's genus:

Stypella Möller emend. Fructifications resupinate, determinate, tubercular, densely gregarious, and united by a delicate subiculum which often disappears upon drying, often anastomosing or confluent into a continuous layer; texture soft, waxy-gelatinous when moist, drying to an almost imperceptible film; probasidia obpyriform to subglobose, becoming longitudinally septate into 2–4 cells, each cell bearing an epibasidium tipped by a sterigma and a spore; gloeocystidia or paraphysoids present, borne in clusters and serving as the centers of the tubercles; spores usually germinating by repetition.

If the genus should find acceptance on this basis, there are several other species now distributed amongst *Exidia, Sebacina* and *Tremella* which should probably be included.

PLATE VI

Photographs by Mr. Donald P. Rogers

Stypella minor Möller. Fig. 1. Mount in Amann's medium, with Nigrosin, showing basidia and paraphysoids, x 233. Fig. 2. Surface view of pustules, soaked, showing anastomoses and subicular hyphae, x 55. Fig. 3. Fructification of scanty growth, x 11; a. dry; b. soaked. Fig. 4. Fructification of denser growth, x 11; a. dry, showing tow-like character; b. soaked, showing anastomosing pustules.


1
3a
3b
4a
4b

THREE NEW SPECIES OF MYXOMYCETES

HENRY C. GILBERT

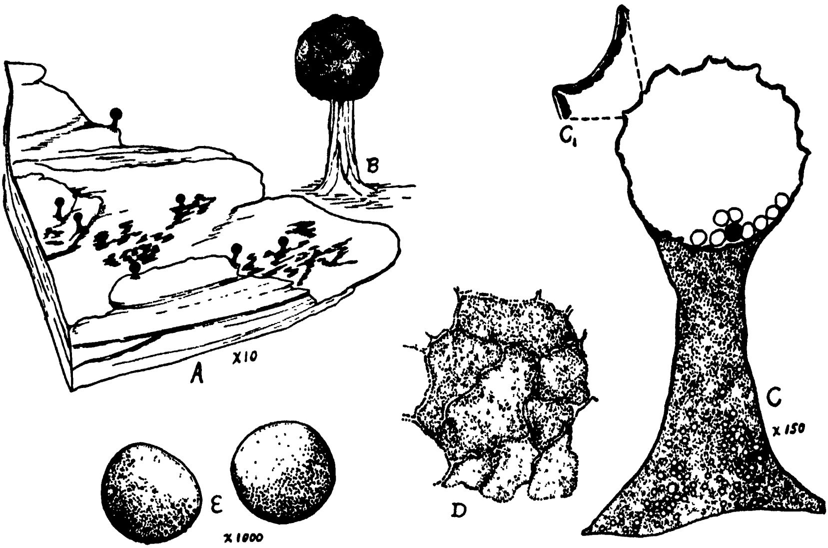
The three species of Myxomycetes presented here were found on the bark of living trees during a study of bark inhabiting forms made in Iowa in 1932 and 1933. A brief report of the known forms found during this study was published in August, 1933.[1] Bark samples collected from various trees were cultured in moist chambers, thus simulating damp or rainy weather for a sufficient length of time to permit maturation.

The fact that these were found and are described from material developed in moist chambers immediately raises a question as to their normal development. In the case of the known species found in this study the sporangia formed in the moist chambers were found to be typical. Furthermore, the sporangia were more uniform and perfect in their development than collections of the same species which had developed in the field. The two species of *Macbrideola,* here described, are very similar. If collected in the field the species *M. decapillata* might be considered a poorly developed form of *M. scintillans.* In the moist chamber, however, the conditions were the same for both, and, as experience has proved, were optimum or nearly so for development. The greater simplicity of *M. decapillata* in this case cannot be ascribed to external conditions.

The possibility of collecting these species mature in the field is probably remote due to their minute size and scattered habit. The number of times that they have developed on bark cultures shows that they are actually common and should be considered rare only in the matter of finding them. The culture method is recommended both for collection and study. It is to be expected that these and perhaps other new Myxomycetes will be found on the bark of living trees wherever climatic conditions favor the growth of algae or lichens on the bark.

Hymenobolina pedicellata sp. nov. Sporangiis late dispersis, globosis, fusce brunneis vel nigris, plerumque corrugatis, stipitatis vel sessilibus, 75–175μ diametro; stipite crasso, sulcato, opaco, scrutis farto, fusco vel cum substrato concolori, 100–250μ longo; peridio

[1] Gilbert, H. C., and G. W. Martin, Myxomycetes found on the bark of living trees. Univ. Ia. Studies Nat. Hist. 15(3): 1–8. 1933.



Text figure 1. *Hymenobolina pedicellata.* A, habit sketch; B, a single sporangium enlarged; C, longitudinal section of a sporangium containing a few spores. A detailed cross-section of the peridium is shown at C_1; D, surface view of a piece of peridium; E, spores.

membranoso granula includente, sporis globosis, in cumulo fuscis, sub lente pallido-brunneis, uno latere incoloribus, levibus vel verrucis minutis, 12–14μ diametro.

Sporangia widely scattered, globose, dark brown or black, usually wrinkled, stipitate or sessile, 75–175μ in diameter; stipe thick, furrowed, opaque and stuffed with refuse, often including spores and Protococcus cells, dark or the color of the substratum, 100–250μ long; peridium membranous but containing granular refuse in the inner part, continuous with the surface of the stipe and also forming a wall between the contents of the stipe and the sporangium, on drying forming irregular plates and thin lines of dehiscence; spores globose, dark brown in mass, by transmitted light light brown with a colorless area on one side, contents rose tinted, smooth or faintly and finely warted, 12–14μ in diameter.

Type specimen: Gilbert No. 2117, Milford, Iowa, July 16, 1932.

Habitat: the bark of living trees of Ulmus, in slime flux areas or other wet places, often associated with *Protococcus,* and with other bark inhabiting Myxomycetes.

This minute Myxomycete lives in the thin layer of wet waste matter on the surface of the bark of trees. The small plasmodia seem to develop like those of *Hymenobolina parasitica,* each forming but one sporangium. The sporangia are scattered and often few will be found. They are slow to mature and many dry before the spores are formed. A cross-section of the peridium shows a thin translucent layer on the outside with more or less waste matter on the inside as illustrated in text figure 1, C. The separation of this inner granular waste matter into irregular plates forms thin lines of dehiscence. These are less numerous and less evident when there is little waste matter in the peridium.

This new species undoubtedly belongs to the family *Liceaceae* yet it does not conform to any one of the present genera. Rather than erect a new genus it is placed in *Hymenobolina* for the present. The reasons for this may be briefly stated as follows. The species *Hymenobolina parasitica* does not conform to the original generic limitations set for it. The genus description states that the plasmodium is parasitic on lichens and algae. I have observed that many plasmodia of *H. parasitica* develop and fruit in the absence of either lichens or algae. A membranous lid for the sporangium is also required in the generic description but many sporangia otherwise typically *H. parasitica* do not develop membranous lids. The genus *Hymenobolina* is described as having sessile sporangia. In this new species I consider the stipitate sporangia as typical yet there are some sessile and nearly sessile sporangia found among the stipitate ones in various collections. The spores of this new species are very much like those of *Hymenobolina* and definitely relate it to that genus. It is like this old genus also both in habit and in habitat.

More detailed study of these minute forms is needed. Since such forms as *H. parasitica* develop but one sporangium from one plasmodium it is entirely possible that two sporangia very close together may be two species. The idea of intergrading forms and variation in species of this kind cannot be considered in the same way as it is in the case of colonial forms. Differences which have been observed such as presence or absence of a stipe, or possession or lack of a definite lid may actually be species differences in these uni-sporangiate forms.

MACBRIDEOLA gen. nov. Sporangiis stipitatis; stipite pellucido, cavo, sicut columella in sporangium inserto; plerumque sine capil-

litio; peridio membranoso, pellucido, evanido vel persistente; sporis brunneis.

Sporangia stipitate; stipe translucent, appearing hollow, extending into the sporangium as a columella; capillitium typically lacking although divisions of the columella may be found in some sporangia; peridium membranous, translucent, evanescent or persistent; spores brown. Type species *M. scintillans.*

This new genus is named in honor of Dr. Thomas H. Macbride, late President Emeritus of the University of Iowa. For more than forty years Dr. Macbride collected and studied the Myxomycetes. His contributions to our knowledge of the North American forms of this group are the greatest ever made by any one person. This new genus is particularly appropriate to commemorate Dr. Macbride's work because the type species, *M. scintillans,* finds its ideal habitat in the beautiful woodlands of the Iowa country in which Dr. Macbride labored. It is hoped that this beautiful though minute Myxomycete may bear this name and ever remind us of the work of a great and good scholar.

Included in this new genus are two forms not referable to any of the present genera but showing relationship to several in various characteristics. In the type species the columella is usually undivided and like that of *Enerthenema.* The peridium is persistent and even more firmly attached to the columella than the similar attachments in *Barbeyella.* The stipe seems more like that of a *Comatricha* or *Lamproderma.* The rudiments of capillitium found in some sporangia suggest that it may be related to *Echinostelium.* In the classification given by Lister[2] it would come under the *Stemonitaceae* while in that of Macbride[3] it would be in the *Lamprodermaceae.*

Macbrideola scintillans sp. nov. Sporangiis dispersis, globosis, fusce brunneis vel colore aeneo, 75–125μ diametro; stipite subulato, pellucido, cavo, ad basim flavo, supra brunneo, in sporangium inserto, 50–100μ longo; peridio tenui, nitido, pellucido, tenaci, ad collumellam haerente; columella deminuente, percurrente, in peridio merso; capillitio nullo; sporis globosis, verrucis magnis, magnitudine et distributione irregularibus, ornatis, 8–9μ diametro.

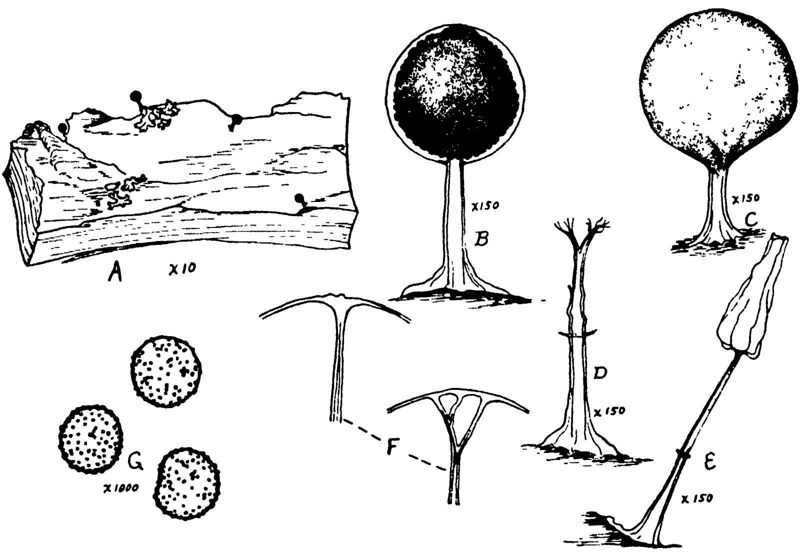
Sporangia scattered, globose, dark brown or metallic bronze, 75–

[2] Lister, G., Mycetozoa, London, 1925.
[3] Macbride, T. H., North American Slime-Moulds, New York, 1922.

125μ diameter; stipe tapering, translucent, appearing hollow, yellow at the base, brown above, continuing into the sporangium, 50–100μ long; peridium thin, shining, translucent, tough, strongly attached to the columella; columella tapering, reaching the apex where it fuses with the peridium; capillitium lacking; spores globose, thick walled, brown, marked with large warts irregular in shape and distribution, 8–9μ diameter.

Type: Gilbert No. 1741. Iowa City, Iowa. May 14, 1932.

Habitat: the bark of living trees of *Ulmus, Quercus, Tilia* and *Juglans.*



Text figure 2. *Macbrideola scintallans.* A, habit sketch; B, a mature sporangium by transmitted light showing the spore mass shrunk away from the translucent peridium; C, a large sporangium; D, showing unusual divisions of the tip of the columella; E, stipe and typical columella with the tough peridium turned inside out during spore dispersal; F, showing attachment of columella and peridium; G, spores.

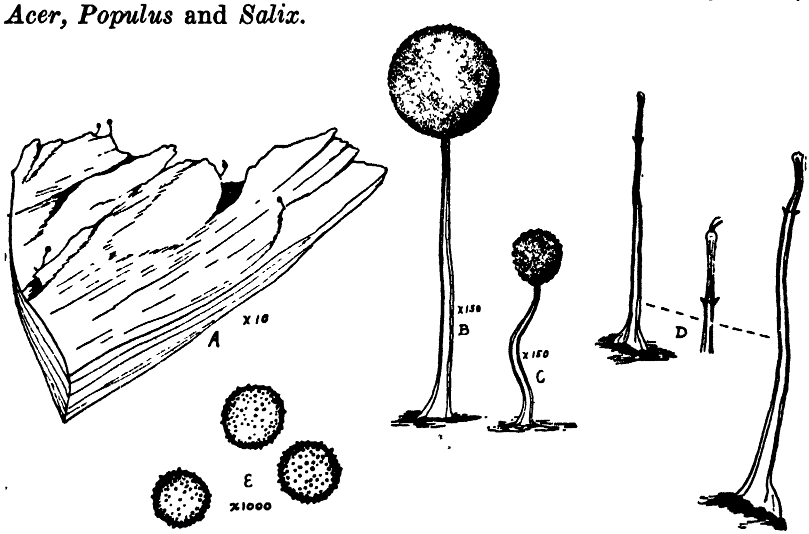
This minute form has been collected a number of times. The stipe, peridium and spores seem to be constant in their characteristics. The variations found in the columella are not sufficient to mislead one in identification. It is often associated with other bark inhabiting Myxomycetes.

Macbrideola decapillata sp. nov. Sporangiis late dispersis, globosis, fusce brunneis, 50–100μ diametro; stipite gracili, pellucido, cavo ad basim luteo, supra brunneo, in sporangium insertum, 125–250μ altitudine; peridio tenuissimo, hyalino, evanido, circum stipitem annulum relinquente; columella ad medium sporangium pertinens; capillitio nullo; sporis globosis, circum columellam agglutinatis, cumulo fusce brunneis, sub lente spadiceis vel violaceis, verrucosis, 7–9μ diametro.

Sporangia widely scattered, globose, dark brown, 50–100μ in diameter; stipe slender, translucent, appearing hollow, yellow at the base and brown above, continuing into the sporangium, 125–250μ long; peridium very thin, hyaline, early evanescent leaving a ring about the stipe; columella about half the diameter of the sporangium, rounded at the end or rarely with short protuberances; capillitium lacking; spores globose, agglutinated around the columella, dark brown in mass, brown or violaceous by transmitted light, thick walled, marked with warts irregular in size and distribution, 7–9μ in diameter.

Type: Gilbert No. 2184. Waverly, Iowa. July 30, 1932.

Habitat: the bark of living trees of *Ulmus, Juglans, Quercus, Acer, Populus* and *Salix.*



Text-figure 3. ***Macbrideola decapillata.*** **A, habit sketch; B, a very large, young sporangium with peridium yet intact; C, a small sporangium dry and with peridium gone; D, types of stipe and columella; E, spores.**

This minute species is but little larger than *Echinostelium* and much like it in structure. Collection and handling are difficult. The peridium drops away in drying. The spores are but slightly agglutinated if well matured and usually drop off if the mount is handled much after drying. The result is that from numerous collections I have left but little herbarium material. It is advisable with species as delicate as this to make a few permanent slide mounts before the collection is dried. The small size, long stipe and evanescent peridium set this form apart from *M. scintillans*.

All of my collections of Myxomycetes have been placed in the Department of Botany, Oregon State College, Corvallis, Oregon. Type specimens of these new species will also be found at the University of Iowa, Iowa City, Iowa, and in the United States National Museum at Washington, D. C.

THE BASIDIUM

Donald P. Rogers

It is a truism that during the development of mycology increasing dependence has come to be placed upon microscopic criteria in the classification of the fungi. Character of spore and minute structure of sporocarp have been found to furnish the most reliable basis attainable for the delimitation and identification of species. Arguing from this, a number of workers have erected genera or even larger categories on characters which have been proved valid only in the distinguishing of species—on spore ornamentation, it may be, or on various accessory hymenial organs. Saccardo's sporologic arrangement of the imperfecti and pyrenomycetes is the most striking example of such inappropriate consistency; only slightly less thoroughly scholastic are some of the modern revisions of the hymenomycetes.

Since the time of Tulasne the morphology of the basidium has been an important factor in the classification of the basidiomycetes. That great mycologist left lucid and accurate descriptions of the principal basidial types known today. Present understanding of the basidium may be said to begin with his work; present taxonomic arrangements of the basidiomycetes, insofar as they are not Friesian, are founded upon relationships which he described on grounds of basidial morphology. But his work ended before he had expressed his conclusions in a system; and it was left to later mycologists, and above all to Patouillard, to embody his method and results in classification. Patouillard based his arrangement, (20) the nearest approach to a natural system that has yet been proposed, on other microscopic criteria in addition to basidial form—on texture of basidiocarp, accessory hymenial organs, spore germination—and, to an extent, on the macroscopic character of hymenial configuration; his principal groups, however, are based on the basidium. Other workers have gone much farther than he in microscopic subdivision; still others have not placed a high value on minute as opposed to gross characters; perhaps the majority have assented to the removal of phragmobasidiate forms from holobasidiate groups, but among the latter have not seen fit to depart from Friesian orthodoxy. This is essentially an acceptance of the evi-

dence of the basidium, as far as that has been made clear, and a rejection of other microscopic criteria as applied to the higher taxonomic categories.

It may be asserted that the greater part of whatever truth and permanence inhere in the present conceptions of basidiomycete relations has been attained through study of the basidium. Both the kinship of the rusts, smuts, gasteromycetes with the hymenomycetes and the distribution among its natural subdivisions of the fungi included in this last vaguely defined group have been deduced from basidial characters. The sharp separation of the gasteromycetes from the hymenomycetes, a taxonomic convention comparable with the division between the pteridophytes and spermatophytes, is unnatural in exactly the degree in which it takes no cognizance of the basidial evidence. It is not improbable that any future approximation of ultimate truth concerning basidiomycete relations will be based on observation and interpretation of the basidium. Meanwhile it appears desirable and expedient to apply such knowledge as is available to the working out of a tentative series of relations among these fungi and to the criticism of some of the accepted taxonomic arrangements.

The antecedents of the basidium and the ancestors of the basodiomycetes are in all probability to be found somewhere among the less highly specialized ascomycetes. The evidence for this statement has been treated in detail by several authors, notably by Gäumann (16, pp. 398–404; 17, pp. 420–426). Briefly, it has been shown, largely on cytological grounds, that the basidium is an organ completely homologous with the ascus, differing fundamentally only in the exogenous formation of the definitive spores. Furthermore, only among the ascomycetes is there to be found a structure even remotely assimilable to the dikaryophase of the basidiomycetes, already highly developed even in the simplest forms; and the homologies between the ascogenous thallus and the basidiomycete diplont are many and striking. The relation between the cytologically antithetic generations in the two classes is roughly comparable to that between those of the bryophytes and the tracheates: in the ascomycetes the haplont is well developed and the diplont present only as a parasitic fruiting thallus; while in the basidiomycetes the haplont becomes progressively more insignificant and the diplont, an assimilative as well as a fruiting phase, occupies a larger and larger part of the cycle. It appears proper to regard this shift

in the development of the two phases, which, as Gäumann (16, pp. 371–373; 17, pp. 393–395) has pointed out, commences among the simplest of the ascomycetes, as a continuous process and not two distinct ones, to see in the increasing emphasis upon the diplont among the basidiomycetes a phyletic continuation of a line of development that has not been completed anywhere among the ascomycetes. There appears no good reason to doubt the complete homology of the crozier of the ascogenous hypha and the clamp of the basidiomycete dikarophase. The presence of double fusion and reduction in certain of the higher ascomycetes, even if it can be said to be established, offers no very serious obstacle to the homologies here described. It may be that the basidiomycetes represent one general type of evolution and the more highly developed ascomycetes another from a primitive ascus type lacking any special mechanism for spore discharge. There is no serious objection, however, to the derivation of the basidium from some more highly developed, explosive ascus.

No such high degree of probability can be predicated of any hypothesis which seeks to establish which particular basidial type is nearest to the ascomycetous ancestor. Perhaps the greatest certainty belongs to the negative assertion that the "primitive basidium" is not to be found among the biologically highly specialized groups of the rusts and smuts. The primitiveness of the smuts was formerly asserted on grounds of variability in spore number and in the organization of the promycelium. The development of the promycelium from a thick-walled resting spore and the cytological phenomena in the smuts, to name but two characters, oppose this theory, and it is no longer of any importance. Phyletic transition through the rusts is argued chiefly on the asserted presence among them of "sex organs"—that is to say, female gametangia and receptive organs and male gametes. There is nothing in the recent careful accounts of Craigie (11) and R. Allen (1) to indicate a fundamental dissimilarity between the manner of initiation of the dikaryophase in the rusts and the hypha-conidium fusions of the hymenomycetes, and it seems preferable to follow Gäumann (16, p. 454; 17, p. 591) in interpreting copulation in the rusts as essentially somatogamous. The rust basidium, with its specialized organ of conservation (teliospore), is no nearer than that of the smuts to the ascus. For the rest, "Es ist doch unmöglich, Pilze, deren ganze Organization durch ihren extremen Parasitismus bedingt ist, als

Vorläufer solcher Pilzgruppen anzusehen, die ausschliesslich oder vorwiegend Saprophyten enthalten" (Janchen, quoted by Neuhoff (19, p. 278)). No more credible is the derivation advanced chiefly by the Besseys (3, 4, 5) of the holobasidiate series from hypogaeous ascomycetes, through similarly hypogaeous gasteromycetes, by progressive reduction of the fruiting body, or that suggested by C. W. Dodge, (12) which similarly would have the higher hymenomycetes consist essentially of angiocarps become gymnocarpous. Either would, in general, constitute an utterly unparalleled example of evolutionary back-tracking, and of a large and extremely varied group arising from forms highly advanced, highly specialized, even to the extent of being degenerate in some of their most characteristic aspects. Specifically, the transition in spore production *among angiocarpous fungi* from endogenous to exogenous-sessile to exogenous-sterigmate and ultimately to exogenous-expulsive—the violent discharge of the spore from the sterigma is surely a fundamental basidiomycete character—is difficult of defense; what is true of the first of the schemes under consideration is true, to a slighter extent, of the second. Furthermore, sterigmate and sessile spores frequently occur within a single genus, in numerous widely separated genera of the gasteromycetes; the transition from astergmate to sterigmate would under the theory in question have occurred many times over without having anywhere the slightest biological significance. The reading of the series in the reverse order—propulsive, sterigmate-deciduous, sessile—is biologically defensible; the sterigma is incomprehensible except as an organ contributing to spore dispersal, and consequently cannot have arisen, but only have degenerated, in forms where it disappears long before the spores are freed from the spore cavity. The evolution of a fairly extensive haplont from the reduced condition typical of the gasteromycetes, in which it is represented by only a brief early stage in basidiospore development, is equally improbable, and an equally conclusive objection to the derivation of gymnocarpous from angiocarpous basidiomycetes.

The most primitive basidium is therefore to be sought somewhere among the saprobic gymnocarps—more specifically, among those *Tremellales* and *Thelephoraceae* which do not show marked somatic development. There is not the absurdity that Janchen and Neuhoff see in positing some phragmobasidium as the primitive type. Once granted the proposition that the ascus, of a sort either lacking or

secondarily deprived of the means of discharging its spores outright, has developed exogenous spore production, some sort of case can be made out for almost any basidial type; witness Buller's argument (8) for an auriculariaceous basidium and Neuhoff's (19) for the holobasidium. Although there is no incontrovertible evidence that the evolution of the basidium has at any level been monophyletic, yet the numerous fundamental similarities among the various basidial types speak for their origin from an at most greatly restricted ancestral group. The complete series of basidial types being represented in resupinate forms only, it is proper to reason that the greater part of the fundamental morphological evolution has occurred at this level of development, and also to postulate the rise of the basidiomycetes from some such resupinate form as *Ascocorticium*. Further, the sterigma-spore relation, as has been shown by Buller, is morphologically and physiologically a fixed one throughout the gymnocarpous basidiomycetes; this being the case, it has either developed *de novo*—and scarcely more than once—in the course of basidial evolution, or else it represents, likely in a modified form, a biological adaptation already present in the ancestral ascomycete. The first implies development of all basidiomycetes from a single basidiomycetous ancestor; polyphyletic evolution of the group has any considerable probability only under the second hypothesis. Further consideration of the question must be founded upon a more minute examination of the various basidial types, to be undertaken in the following pages.

The concept of basidial morphology which offers the most satisfactory basis for comparative study is that proposed by Neuhoff (19) as the fruit of his studies of the *Auriculariaceae* and *Tremellaceae*. The structurally complex basidium of these groups typically arises as a vesiculose body, containing at first the basidial dikaryon and later the zygote. This primary vesicle may constitute a more or less protracted resting stage and usually remains morphologically distinguishable throughout the development of the organ; it is the probasidium. Neuhoff chooses to interpret it ecologically, as essentially a resting organ; but while it assuredly reaches its highest development as a sclerotized resting cell, there are everywhere among the basidiomycetes resting stages in basidial ontogeny which cannot properly be assimilated to the probasidium. It therefore appears preferable to interpret it morphologically, to see in it the actual vestigial ascus vesicle, which in most holobasidia is no longer

differentiated. An obvious corollary of this assumption is that the primitive basidium must be one having a probasidium. The mature basidium in the heterobasidiomycetes under consideration typically consists of a probasidium together with one or several more or less tubular appendages borne upon it, serving to separate the place of spore formation from the place of origin of the basidium and of karyogamy, to raise the spores to and beyond the surface of the basidiocarp, and serving also in some degree in the stead of the basidium as a whole in actual spore formation. These appendages are called by Neuhoff the epibasidia, and in the mature basidium possessing them the original vesicle is called the hypobasidium. Their number is most frequently four if meiosis occurs in the hypobasidium; if the diploid nucleus remains undivided long after the "germination" of the probasidium, only one epibasidium is formed, and the nucleus undergoes reduction some time after migrating into it from the hypobasidium. Neuhoff advances the profitable hypothesis that the morphological development was originally, in the course of phylogeny, the result of the cytologic, that the formation of the four epibasidia was originally occasioned by the thrusting out of the wall of the primary vesicle by the four haploid nuclei independently, and the single epibasidium by the activity of the entire protoplast acting as a unit with its single nucleus. Following him in this, it seems proper to consider that the basidiomycetes present fundamentally two phyletic tendencies, to divide them for purposes of comparative morphology between forms having epibasidial and those having hypobasidial meiosis. This is not to accept in the slightest degree the two basidiomycete series, the stichobasidial and the chiastobasidial, recognized by Juel; the folly of that arrangement has been demonstrated many times over, notably by Neuhoff. Nor is it intended to suggest by the inclusion of all basidiomycetes in one group or the other that there are in simplified types ontogenetic stages which correspond to the morphological differentiations of the more complex, as implied by Donk (13, pp. 78–81). His distinction between probasidium, "that part or stage in which karyogamy occurs," and metabasidium, "that part or stage in which the diploid nucleus divides," introduces a false complexity into the interpretation of the phylogenetically simplified basidium of the *Hymeniales*; in this group there is no epibasidium, and no need for such a distinction as Donk's. The two series here noted justify themselves by furnishing a theoretical basis for observed morphological differences.

It is a necessary part of any reasoning based on Neuhoff's concept that in no case can the epibasidium be equated to the sterigma. The sterigma of the heterobasidiomycetes is exactly what it is in the homobasidiomycetes, a subulate organ—Tulasne's *spicule* describes it—on which the spore is borne and which serves in its discharge after the manner described by Buller; sterigmata are to be found borne upon the tips or sides of epibasidia. The epibasidia differ not only in function and morphology, but also in their homologies, from the sterigmata; whereas they represent in a greater or less degree either the ascospores themselves (when several epibasidia are present) or else the germinating ascus protoplast (when there is but one), the sterigma and basidiospore are better homologized respectively with the sterigma and conidium or secondary spore by which certain ascospores are known to germinate. This conception, suggested by the author (21) on the basis of the *Tulasnella* basidium, finds its confirmation in its applicability to the interpretation of the various hypha-like complexities of which the epibasidia in their development are capable. Until the virtual completion of the present discussion it was not known to him that the same conception—that of the germinating ascus—had long ago been carefully developed by Vuillemin. "Une baside est un asque dont chaque cellule-fille, avant de passer à l'état de spore, fait saillie au dehors et se transforme en une sorte de conidie pour mieux s'adapter au transport par le vent." (22)

The three major divisions of the class *Basidiomycetes*—*Heterobasidiomycetes, Hymeniales* (hymenomycetes *sensu stricto*), *Gasteromycetes*—can be accurately delimited and established as reasonably homogeneous groups by the general properties of the basidium. Among the *Heterobasidiomycetes* the basidium (Plate VII, fig. 1–20) generally shows morphological differentiation into hypo- and epibasidium; it frequently shows regular septation; and most notable of all, not only is there great variation in basidial morphology from group to group and from species to species, but under suboptimum conditions the heterobasidiomycete basidium is capable of any of the modifications possible to ordinary mycelium—indefinite elongation, repeated irregular septation, branching, oidium formation—and of direct germination, by hyphae instead of by basidiospores. This variability is reflected in the basidiospores, in their occasional or regular septation and their germination by repetition or conidia as well as directly. So universal is this capac-

ity for variation, phyletic and ontogenetic, that it may well be taken to be the surest criterion of the group; and the types of response possible to the more typical forms must be taken into account in any attempt at interpretation of the more aberrant. It is worthy of note here that the suboptimum condition most frequently responsible for such variations in heterobasidia is the presence of excessive moisture—either saturated atmosphere or a highly deliquescent hymenial matrix—and that the biological significance of the variability is to be seen in the necessity for the gonotocont to reach above a water film if the products of meiosis are to be discharged as air-borne spores; either an appendage (epibasidium) elongates until it reaches the surface, or else the potential spore protoplast develops in hyphal fashion. Excessive moisture has likewise been shown to be responsible in some cases for ascospore germination by conidia, and for germination of ascospores while in the ascus. Neuhoff attempts to elucidate basidial evolution as the varying response to desiccation of an already established homobasidial type. Insofar as ecological factors can be held to be operative, it would appear better to concede at least an equal potency to the factor of humectation, as an unfavorable influence to be overcome, and *pari passu,* as an influence permitting precocious germination, as suggested by Vuillemin, and to attempt, as here, to recognize its possible influence in the original evolution of an exosporous tetrasporocyte.

The remaining basidiomycetes, united in the subclass *Homobasidiomycetes,* are uniformly characterized by the lack of differentiated hypo- and epibasidia and by the absence of septation or of any marked potentiality for ontogenetic variation in the basidium. The subclass is commonly divided into the *Hymeniales* (or *Hymenomycetes,* in a restricted sense), characterized by being at maturity gymnocarpous, and the *Gasteromycetes,* all angiocarpous. The groups are in an equal degree separable, and their relations much better indicated, by basidial characters. In striking contrast to the *Heterobasidiomycetes,* which are marked by variability, the *Hymeniales* show in basidial morphology a high degree of fundamental fixity. The basidium of the *Hymeniales* (Plate VII, fig. 21–26), the homobasidium *par excellence,* throughout the group shows no variation, with comparatively minor exceptions, other than in the proportions of its various parts; it consists of an ellipsoid to cylindric or clavate vesicle which developes only in size from the

time it is separated from the parent hypha to the beginnings of the sterigmata. It constitutes a simplified type, with no fundamental morphological elaboration except the sterigma by which violent spore ejection is accomplished, a simplification which once having been achieved in phyletic development persists throughout the range of basidiocarp evolution. The basidium still serves as a valid indication of taxonomic relations, but it is in this group of less use than elsewhere in phylogenetic elucidation.

Just as the heterobasidial types are comprehensible in the generalization of primitive variability and the hymenomycete basidium in that of simplification and fixity, so the basidia of the *Gasteromycetes* (Plate VII, fig. 27–29) are universally characterized by the degenerative variability that is occasioned by loss of function. The simple vesicle is retained; but the sterigma, no longer serving as a projector for the spore, in some forms becomes grotesquely long and tenuous and in others progressively shortened and obsolescent, until the spore is borne directly upon the basal cell. Where the sterigma remains the spore is borne not obliquely, as in all forms where forcible discharge occurs, but directly along its axis. (7) Such degenerative variations, however marked, are far from fundamental; they are to be interpreted only as secondary responses to an originally teratological or ecological modification of gymnocarpous fungi, and indicate the closest kinship of some of the gasteromycetous groups in which they are least advanced with comparable forms among the *Hymeniales*.

"As the founder of the Naples Biological Station has caustically remarked, it is a curious fact that every investigator is convinced that the type which he is studying has a monopoly of most of the primitive features, and that other types are secondarily modified." (18) It seems no more than fair to preface with such a caveat the suggestion that the *Tulasnella* basidium (Plate VII, fig. 1–5), as highly organized as any existent type, is phylogenetically closest of existent types to the antecedent ascus. It consists invariably of a more or less pyriform hypobasidium, in which occur karyogamy and meiosis, and four to eight epibasidia borne upon it; these receive the nuclei and cytoplasm from the hypobasidium, are separated from it by basal septa, and either at once or following a division of the single nucleus each contains elongate apically to produce above the surface of the fructification sterigmata and spores. There appears no more satisfactory hypothesis for the formation of the

sharply delimited mature epibasidia, which may be capable of producing basidiospores while the hypobasidium beneath them is collapsed and disintegrating, than that of their essential homology with ascospores—that is, the interpretation of them as an alternative mode of development of the protoplasts otherwise destined to mature as ascospores. The *Tulasnella* basidium, then, the one in which the ascospore stage is most completely retained in basidial ontogeny, is held to be most primitive. It may be noted here that the subdivision of the family *Tulasnellaceae* was earlier based, as in other groups, on presence or absence of gloeocystidia, but that basidial morphology, here as elsewhere, has been urged as a much more reliable indication of such lesser, as of more general, relationships.

The *Tremella* type (Plate VII, fig. 6) represents another development of the basidium with hypobasidial meiosis: here the walls separating the tetracyte protoplasts typically are laid down immediately after the second division, before the initiation of the epibasidial outgrowths; the hypobasidium having become "cruciately" septate by the more or less regular formation of three longitudinal walls, each segment, like the epibasidium in *Tulasnella,* proceeds independently to the formation of an apical filament bearing a sterigma and basidiospore. It may well be that the tremellaceous basidium has been derived directly from the tulasnellaceous type, by the transfer of basidial septation to an earlier point in growth. The possibility of independent derivation from the ascus is not, however, to be lost sight of completely. It is perhaps noteworthy also that there occur in certain resupinate species of the *Tremellaceae* (*Sebacina,* subgenus *Bourdotia*), along with longitudinally septate basidia, occasional others in which no septa are to be found even when the epibasidia have attained a considerable length; it has not yet been shown whether the hypobasidium remains undivided through the time of spore formation. At any event, there is here a suggestion of a possible derivation of the holobasidium; but the relations among the resupinate basidiomycetes are too complex, and variability too great, for this suggestion to be embodied in a definite hypothesis. It is to be borne in mind that such tardy septation is no more than a rare anomaly, perhaps only temporary even in the basidia in which it occurs; it is nevertheless valid as a suggestion of what may have occurred in phylogenetic history.

The basidial form characteristic of the *Dacrymycetaceae* offers an anomaly which has hitherto received no acceptable elucidation. The basidium (Plate VII, fig. 7) here arises as a considerably elongate clavate organ, in which karyogamy and meiosis occur; two very thick, long, horn-like appendages arise from the periphery of its truncate summit, each bearing at its tip a sterigma and spore. There is nowhere in the basidium any regular septation; but adventitious septa are occasionally formed both in the clavate portion and in the appendages; this, and the invariable germination of the spores by conidia (Plate VII, fig. 8), serve to confirm the assignment of the family to the heterobasidiomycetes. Their great size and their ability to become septate mark the appendages as epibasidia. The clavate portion is the highly modified hypobasidium. As ancestors for the dacrymycetaceous basidium have been suggested the smuts and the equally specialized and aberrant parasitic genus *Kordyanella*; such a derivation, roundabout and tenuous as it is, can scarcely be accepted for forms which somatically and biologically—not to enumerate basidial similarities—show many characteristics of other heterobasidiomycetes among the *Tremellaceae* and *Auriculariaceae*. On the other hand, of a group of the forms included in *Corticium* section *Botryodea* by Bourdot & Galzin, (6) forms showing their essential heterobasidiomycetous nature by possession of long, stout epibasidia and spore germination by repetition, one form, *C. sterigmaticum,* with the reduced number of two epibasidia (Plate VII, fig. 20), shows the most striking resemblance to the *Dacrymyces* type. The epibasidia arise from the cylindric basal cell exactly as in the latter form; except in length of the hypobasidium, there is no difference in form in the two basidia; it appears highly probable that the dacrymycetaceous type has been derived from a form with just such a basidium. The two forms in question show alike a secondary reduction in the number of epibasidia, correlated with larger spores; and the clavate hypobasidium of *Dacrymyces,* as in other groups, represents a response to the development of a compact hymenium. The most primitive member of the *Dacrymycetaceae* is probably, like the corresponding form in other families, a resupinate, *Ceracea*; nodulose, cerebriform, and spathulate fructifications represent an advance in somatic development.

The basidial types characterized by a single epibasidium may have arisen directly from the ascus or with about equal possibility

from the *Tulasnella* basidium, with its undivided basal cell; there seem to be no important grounds for preferring the one hypothesis to the other, the first being here accepted from considerations of logical economy; in either event the transversely septate basidium marks a distinct line of phyletic development. If the primitive auriculariaceous basidium be assumed to be one with a persistent hypobasidium, clearly distinguishable in all stages, an obvious example of it has so far been found only in such *Saccoblastia* material as shows distal germination of the probasidial sac (Plate VII, fig. 9–12). A hypobasidium is perceptible in a lesser degree in other forms, such as *Platygloea* (*Achroomyces*) (19); but in the very nature of the case there cannot be such sharp demarcation between the hypobasidium and a single thick epibasidium as when the appendages are several. The probasidium here passes repeatedly from a persistent, morphologically apparent organ to a stage; this is true to an extent in the atypical *Saccoblastia* basidia, even in that form where, if ever, the probasidium is a sharply delimited organ. The presence of division into hypo- and epibasidium, although not striking, characterizes many of the simple resupinate *Auriculariaceae*. It is, however, no great step from this to the situation in which there is no interruption in development from initial cell to mature basidium and no marked delimitation of basidial parts; and the two are to be found side by side. In *Iola* and *Eocronartium*, forms entirely comparable biologically and doubtless very closely related phylogenetically, the hypobasidium is respectively present and absent; in the somatically highly developed genus *Septobasidium* (Plate VII, fig. 15) both types occur, without showing correlation with other characters. In *Auricularia* (Plate VII, fig. 14) the hypobasidium is entirely lacking; in *Helicobasidium purpureum* (Plate VII, fig. 13) there is an evident probasidial stage but no delimitation of two parts in the mature basidium. The epibasidium likewise is capable of varying emphasis; in *Saccoblastia* among the more primitive forms and *Septobasidium* among the more advanced the portion in which meiosis and spore formation occur is often abstricted (Plate VII, fig. 12) and, like the *Tulasnella* epibasidium, capable of proceeding with its functions while the remainder of the basidium collapses beneath it or is separated completely from it. The manner of bearing the spores also varies; in *Auricularia* and *Platygloea*, where the mature basidia form a palisade, the epibasidial segments put out each a filament which reaches to the sur-

face before producing a sterigma and spore; this is the equivalent of the filament which carries the spore to the surface in those tulasnellaceous forms (*Gloeotulasnella*) in which the basidia are embedded in a gelatinous matrix. In other *Auriculariaceae* with less compact hymenia the basidia are curved so as to expose the whole convex side at the surface, and the sterigmata arise directly from the epibasidial segments (Plate VII, fig. 13), as in *Tulasnella violea*.

If considerations already advanced here are given adequate weight it would appear impossible to doubt seriously that the *Uredinales* have arisen not from non-basidiomycetous but rather from auriculariaceous ancestors; the morphology of the basidium alone is incontrovertible evidence for this. The teliospores are sclerotized probasidia such as are already present among the *Auriculariaceae,* and the so-called rust promycelium is an epibasidium (note Fig. 15, of *Septobasidium,* which would serve well as a diagram of a germinating teliospore). In the course of the evolution of the group as parasites there has been infinite variation in the arrangement of the basidia, in biological relations, in accessory spore forms, and, most obviously, in reduction of the basidiocarp; and along with all this the basidium has remained constant to so great an extent that the phylogenetic relations within the order must be deduced almost entirely from what may be regarded as somatic characters. What basidial variation there has been is probably to be accounted for largely by variation in the fruiting layer, and consequently may be regarded as of only secondary significance. It appears logical to follow Neuhoff in considering the uredospores abortive probasidia, and to go beyond him in interpreting the aeciospores as diploid conidia likewise essentially probasidial in nature; such structures are not unknown among the saprobic basidiomycetes, and there is ample evidence for the homology in germination phenomena. The pycniospores, whatever properties may be ascribed to them, are essentially haploid conidia; they may, like conidia in numerous other groups, serve to mix the strains in heterothallic species.

The rusts being essentially *Auriculariaceae* highly evolved as plant parasites obligate throughout their life cycle, the smuts are equally to be characterized as derivatives of the *Auriculariaceae* whose diploid phase has become specialized as a parasite, but whose haplont remains saprobic. In many *Ustilaginales* the basidium

(Plate VII, fig. 16, 18) constitutes the entire haploid portion of the cycle; the numerous conidia or "sprout-cells," which in the forms with septate epibasidium are cut off in considerable numbers from the sides of the segments, conjugate in pairs (Plate VII, fig. 17) and the diplont, which alone is capable of infecting the host, is thus almost at once reinitiated. In other forms the typical basidiospores by which in the *Auriculariaceae* the tetraspore protoplasts germinate are replaced not by conidia but by short hyphal outgrowths—a phenomenon frequently to be observed in more typical members of the heterobasidiomycetes—which conjugate directly (Plate VII, fig. 18), either with those produced by other segments of the same basidium or with those arising from other chlamydospores. In the *Tilletiaceae* transverse septation of the epibasidium becomes completely obsolete, occurring only behind the entire protoplast as it migrates out into the elongate promycelial tube; germination occurs at the apex of the basidium, by sprout-cells or hyphae. In this order, the logical end of the phyletic development commenced with the primitive *Auriculariaceae,* the haplont has almost completely dropped out; since it is incapable of disseminating the fungus to any degree (the basidiospores being unable to withstand even brief desiccation and, with a few exceptions, being incapable of infecting the host), the basidium has degenerated from the form adapted to violent spore discharge and has undergone all sorts of modifications by which the certainty and rapidity of initiation of the diplont are increased: has in a sense passed to partial cleistogamy. These modifications being without exception such as are to be found in any of the heterobasidial types subjected to unfavorable conditions, the terminology and homologies by which other members of the group are best understood are to be applied without qualification to the smuts.

Basidia which not only suggest, but which may be held actually to constitute, transitional forms between the hetero- and homobasidium are, as implied, by no means lacking. A number of the *Botryodea* forms of *Corticium* have basidiocarps exactly like those of species of *Tulasnella* and *Sebacina*; the basidia (Plate VII, fig. 19) arise as inflated subglobose bodies whose resemblance to the phragmobasidiomycete probasidium is very striking; from the apex of such a cell arise four—or in some species only two, or up to eight—thick, greatly elongate appendages, sterigmate at the tips, capable of such irregularities as occasional branching or the formation of septa be-

hind the migrating protoplast; the spores may regularly germinate by repetition. It has already been submitted by the author (21) that these fungi may have arisen from *Tulasnella*-like forms by the dropping out of regular septation in the basidium. The alternative hypothesis that the ancestral form may have been tremellaceous cannot logically be excluded; the *Tremella* basidium and the transitional holobasidium under discussion have this in common, that to a much higher degree than in *Tulasnella* it is in them the hypobasidium, or a segment of it, that is concerned in the production of the spores; in *Tulasnella* it is the almost disarticulate epibasidia. It may even be held, as in the system of Neuhoff, that the holobasidium arose directly from the ascus. To this last, however, it is to be objected that three lines so closely related as the tulasnellaceous, the tremellaceous, and that represented by the transitional holobasidium in question can scarcely have arisen independently of each other; and the structural complexities of the phragmobasidia —notably, that of *Tulasnella*—are much better explained by the hypothesis of ascus germination here supported than as secondary complications, in the sense held by Neuhoff. There is little to choose between derivation from *Tulasnella* and from *Sebacina*; the author, considering the tulasnellaceous basidium the more primitive of the latter two, prefers to see in it the ancestor of the holobasidium. Whatever their origin, according to the criteria here recognized the holobasidiomycetes under discussion are heterobasidial. They are so strikingly intermediate in all their characters and affinities, however, that their assignment to any existent group must bring with it objections. Donk has segregated one portion of the section *Botryodea*, in which these forms are included, as the genus *Botryobasidium*; this he has included in the *Tulasnellaceae*. The affinities of the particular species published for *Botryobasidium* are by no means with *Tulasnella*; they possess short, stout, cylindric basidia (Plate VII, fig. 21) upon which the sterigmata are borne directly, and so far as can be ascertained, never have germination by repetition. The case is rather different for other *Botryodea* species, notably *Corticium sterigmaticum*, *C. cornigerum*, and an undescribed species which in everything except basidial septation is much like *Gloeotulasnella calospora* and *Sebacina calospora*; these are the forms referred to earlier as heterobasidiomycetous. But in actual morphology these forms are no closer to *Tulasnella* or *Sebacina* than the latter are to each other, and cannot properly be

placed in a family with either; the one, as noted, might even be considered one of the *Dacrymycetaceae*; and the only logical disposition of them would be to place them in a family of their own in the heterobasidiomycetes. But it is questionable, in view of the abundant and close transitions toward purely homobasidial types, whether such segregation would result in a clearer expression of relationship; and it appears preferable to accept only generic segregation, treating the group taxonomically as related to *Corticium,* with the express reservation that it *is* transitional, with affinities and characters on the other side of the line. The fungi under discussion, like Vuillemin's protobasidiomycetes, constitute "un group dont il est plus aisé de suivre l'enchaînement que de tracer les limites." (22)

The typical homobasidiomycetes have in all probability arisen from such forms in more than one series. One line of development, whose members are marked by very short, thick-celled hyphae, loose and branching at right angles and often colored, and by stout, short-cylindric basidia borne in botryose fashion (*Botryobasidium*) leads through forms with somewhat spinulose spores (*Tomentella isabellina,* identical in all respects save spore surface with typical species of *Botryobasidium,* and by no means to be separated on this single character) to typical species of *Tomentella,* whose more hypochnoid species show considerable structural similarity, basidial and somatic, with *Botryobasidium. Tomentella,* in turn, is by no means to be separated widely from *Caldesiella*; here again arises a question of practical taxonomy. *Caldesiella,* like *Tomentella* in all respects save one, has been separated not only as a genus but even as a member of a separate family, the *Hydnaceae,* because its hymenium is somewhat nodulose or warted instead of only slightly nodulose or warted, as in *Botryobasidium* and *Tomentella.* It has been well said that the Friesian subdivisions of the hymenomycetes have been defined by arguing backwards from the hymenophore configuration of end forms; to what extent this arrangement must be retained will not be settled until a greater amount of critical work on relationships has been done; but not by the wildest exercise of the imagination can *Caldesiella* be held to be anything other than a *Tomentella* with hymenophore sculpturing in somewhat higher relief; and to separate it by a family line, whatever may be said of the convenience of Friesian characters for architects of keys, is a detrimental and irrational exaggeration. The present

case is cited as only one of numerous possible examples. Either a taxonomic system is to be worked over and modified, endlessly, to express relationship and degrees of relationship, or else it ought to be frankly considered an indexing arrangement and simplified as such, with splittings and bracketings wherever they add to the symmetry of the key. One may then fit fungi as he finds them into named spaces or numbered blanks in already prepared columns, as has been done with imperfects. Patouillardian categories are unquestionably more difficult to follow in keys than Friesian, for one who knows nothing of mycology, but are surely no more disconcerting than for one who recognizes a *Tomentella* under his lens or a *Coniophora* under his microscope to discover that he must find it in the *Hydnaceae* or in *Merulius* of the *Polyporaceae*. It appears not inappropriate, in connection with the difficulties of the more natural classification, to remember the words of an American phanerogam taxonomist, who has said, "I'm not writing keys for boy scouts."

A second homobasidiomycete group set sharply apart by the morphology of its basidium is that made up of the *Urnigera* sections of *Corticium, Gloeocystidium, Grandinia* and *Poria*. The arid, more or less chalky fungi here included bear on a scanty subiculum basidia (Fig. 23–25) which, arising as ovoid or short-clavate bodies, just before spore production elongate considerably, bearing on the summit of a more or less distinct apical portion a crown of slender sterigmata, regularly more than four, and typically eight in number. The urn-shaped basidium and the delicate crown of sterigmata are highly distinctive; it is unthinkable that the group should represent more than a single line of development. This being the case, the forms with smooth hymenia, having or lacking gloeocystidia, those with tuberculose hymenium, even here often partly smooth, and those whose hymenium is thrown into ridges and pits, are assuredly not to be distributed among three families, as though the warted portion of a fructification were more closely related to *Hydnum* and the smooth part to *Thelephora* than either is to the other. This *Urnigera* series demonstrates more clearly than any case yet unsettled the fallacy of subdivision according to hymenial configuration. It is assuredly only a question of time until other series such as this, as the *Tomentella* group, as *Coniophora* and its relatives will be traced out and given adequate taxonomic recognition; as well retain *Tremellodendron* in *Clavaria, Lentzites*

in the *Agaricaceae*, *Tremellodon* in *Hydnum*, *Auricularia* in *Exidia*, as attempt to retain the old groupings as they are now generally allowed to stand. The *Urnigera* basidium itself stands in need of phylogenetic elucidation. There are in *Corticium* in the present all-inclusive sense several minute, arid-crustose forms assigned by Bourdot & Galzin to the section *Athele* which possess the same scanty, fine mycelium, a similar ovoid basidium, and sterigmata ranging in number from four to eight, that mark the *Urnigera* types. There is not the intervening superficially epibasidium-like prolongation before the sterigmata are put out; even so, it seems not unlikely that among them the ancestral type is to be found for the highly characteristic *Urnigera* group. This is no more than a suggestion; whatever may be the affinities of the *Urnigera* basidium, they are not immediately with any of the heterobasidiomycetes; it must be taken to be a secondary development.

There is still the question of the extent to which information can be drawn from the basidium as to the actual relations among the remaining *Hymeniales*. The stout, thin-walled, cornute basidium of *Coniophora* and related species of *Merulius* is quite possibly as constant an indication of a member of this series as are texture of fructification and spore morphology and color. The flexuous, irregular, greatly elongate basidium of *Aleurodiscus* (Plate VII, fig. 26) and the scarcely distinct genera *Dendrothele* and *Vuillemeninia* is a better criterion of the group than other structural characters, and marks it as a phyletic unit. But in the majority of the hymenomycetes the basidium does not furnish sufficient indication of kinship to permit the elaboration from its characters alone of a natural system of classification. There apparently arose from the most primitive holobasidiomycetes a number of lines of development; these may be taken to have persisted as the more strikingly distinct series met with among the somatically little developed *Thelephoraceae*. But higher development involved hymenophore elaboration and the rise of a compact hymenium; a number of lines never progressed so far, and those that did approximated a common clavate, slender-sterigmate basidial type (Plate VII, fig. 22), so closely that differentiation upon basidial characters becomes in the better developed forms scarcely possible. It may well be that differences persist; but these must be studied in extensive series of forms, and in most of the basidiomycetes, particularly those above the *Thelephoraceae* in the present system, probably will never be

of any use except in conjunction with other details of microscopic structure, with texture, color in many cases, and spore morphology. The abundant and varied details of minute morphology to be taken into account in such a study, furthermore, contrary to what is still the almost universal practice, must be treated in combination, as mutually supplementary. Refusals to acquiesce in the arbitrary multiplication of "genera" on the basis of possession of gloeocystidia, of cystidia, of the two together, have been all too few. Among the heterobasidiomycetes there is no such correlation between occurrence of these bodies and basidial as well as other fundamental structural differentiation as would be implied by their extensive use as the sole criteria of new taxonomic segregates. Preliminary studies by the writer would indicate that in the *Thelephoraceae* there is no more connection between the presence of differentiated sterile hymenial organs and such grouping as is clearly indicated by general structure and by such characteristic basidial peculiarities as are present than was found to exist in *Sebacina.* It is significant in this connection to note that most of the sections based on structure that have been erected within *Peniophora* (6) essentially duplicate similar sections in *Corticium,* and that in *Gloeocystidium* have been assembled forms with typical homobasidia, *Urnigera* forms, and even one species (6, p. 261) that failed of being assigned to *Sebacina* (*Bourdotia*) only because the workers who described it failed to observe the basidial septa which (teste Donk) were actually present, this heterogeneous assemblage having no common character but gloeocystidia. Spore ornamentation is a criterion equally delusive when applied uncritically. The spiny *Tomentella* spore is a consistent recognition character for that group; but to put *Corticium tulasnelloideum* and *C. fumosum* (*C. sulphureum* Pers. *non* Fr.) in *Hypochnus* (i. e., *Tomentella*) because their spore wall is roughened is to set a purely verbal consistency against the indications of every possible gross and microscopic character. Relations are to be argued not from verbal but from actually visible characters. The result ultimately to be achieved is a system of classification whose lines will run in many instances perpendicular to those now most commonly recognized, whose series will be phyletic units including, it may be, forms from the ancestral *Thelephoraceae* and from the more highly evolved *Hydnaceae, Polyporaceae, Clavariaceae,* and *Agaricaceae.* The outlines have already been drawn by Patouillard; numbers of minute

but extremely significant forms have been added to the list of known species by Bourdot & Galzin, to the great improvement of the understanding of the whole; they have also applied to a higher and very useful degree the concepts of Patouillard in further critical rearrangement of old as well as new fungi; a highly significant contribution here is being made at this time in the radically revisionary work of Donk. (13, 14)

The arrangement of the *Gasteromycetes* is based even less than that of the *Hymeniales* on knowledge of basidial morphology, or on any minute structural criteria other than disposition of fertile areas. The transition from gymnocarpous to angiocarpous homobasidiomycetes is if anything less abrupt than from hetero- to homobasidial forms. *Secotium agaricoides* and a number of other fungi often included in a family with it can represent, as shown by Conard, (9) nothing but stipitate *Hymeniales*—agarics or boletes—which, perhaps as an ecological response, having failed to open, have set free their spores in the cavity between pileus and stipe. According to Fischer, (15) "the chief characteristic of the gasteromycetes in contradistinction to the hymenomycetes consists in this, that the basidia at the time of spore formation lie within the fruiting body;" this obvious chief taxonomic criterion can by itself explain the other criterion, equally valid but generally disregarded, of basidial morphology, and can account quite satisfactorily for the rise of the whole group. It is not intended to suggest that all gasteromycetes arose from a single form; basidial and especially spore characters as well as general morphology, carried over from the ancestral fungi, show them in all likelihood to be made up of the derivatives of several hymenomycetous groups; but it is a quite satisfactory hypothesis, with no acceptable competitor, that all gasteromycetes have arisen, directly or remotely, from stipitate hymenomycete groups; and relations within the angiocarpous group may to a considerable degree be elucidated by tracing their descent from the various types of more hymenomycete-like members. As earlier noted, the variations in the gasteromycete basidia are comprehensible as representing various degenerative tendencies in a spore-discharge mechanism which is no longer free to discharge its spores, some spores, produced on long, fragile sterigmata (Plate VII, fig. 29), being freed by fracture, and others, borne directly on the basal cell (Plate VII, fig. 27, 28), by disintegration. The arrangement, as well as the form of the sterigmata, shows degener-

ative tendencies: often they are scattered irregularly upon the summit of the basidium; and often they are borne as well upon the sides; the pleurosporous basidium of *Tulostoma* is no more than one striking example of this type. The basidium cannot be here, any more than in the *Hymeniales,* the sole and sufficient criterion of phyletic affinity within the great group; carpophore morphology, among fungi so highly elaborated as these, must be the chief object of study; but, as suggested by Corner, (10) the basidium must be taken into account. If inadequate consideration be given the indications of basidial morphology, phylogenetic absurdities can scarcely fail to result.

In general, it may be asserted that only by study of the basidium can the larger phylogenetic tendencies of the basidiomycetes be understood; that although in many cases basidial morphology cannot alone furnish the key to relationships, in no case is it possible for relations to exist which are denied by basidial characters. The present discussion represents an attempt to evaluate and interpret what information is at hand concerning the basidium. It is intended to set forth the results of the examination of such evidence from the point of view of one phylogenetic concept. There have been, and will yet be, many other points of view, some of them, surely, adapted to the settling of questions which have here only the most unsatisfactory of answers—the question, for example, of which there is here only the beginning of a treatment, of the exact relation existing among the primitive examples of the various types of heterobasidia. "Scientific hypotheses have in their nature no pretension to permanence, and . . . should be judged by their capacity for bringing to light further generalizations, to which, in turn, they yield place." (2)

. . . .

The indebtedness of the author to Neuhoff and Gäumann must have been evident throughout the present discussion to anyone acquainted with their published work; he desires to make general acknowledgment of such indebtedness at this time. To those whose privilege it has been to be present at any discussion of the basidiomycetes by Professor G. W. Martin, his authorship and inspiration of much that has been said here must be even more apparent. To his instructor, Dr. Martin, for constant encouragement and direct assistance in this and throughout his mycological studies, the author wishes here to record his gratitude.

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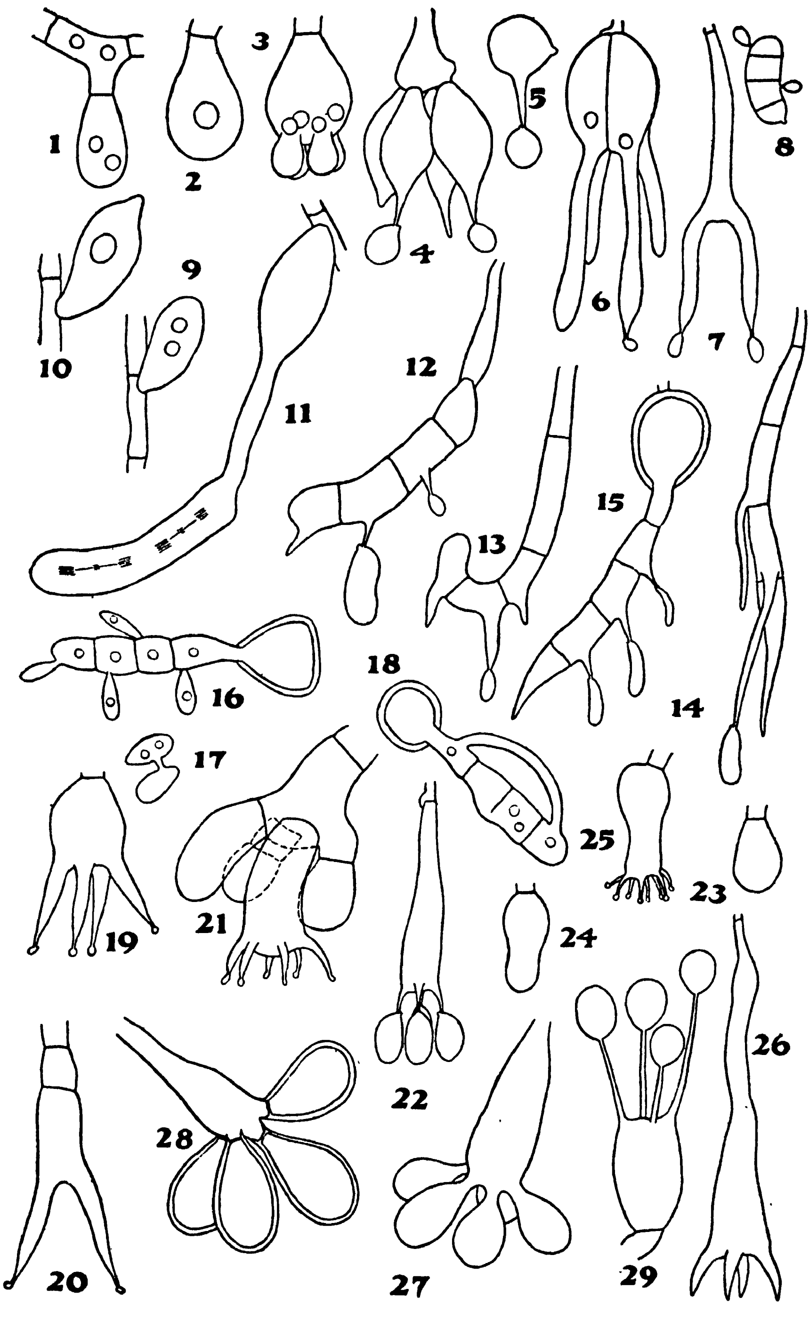
PLATE VII

1–5. *Tulasnella violea.* Stages in basidial development; spore germination by repetition.
6. *Tremella aurantia.*
7, 8. *Dacrymyces.* Basidium; spore germination by conidia.
9–12. *Saccoblastia sebacea.* Probasidia; complete basidium (atypical), with distal origin of epibasidium (reconstructed: diagrammatic); epibasidium with spores.
13. *Helicobasidium purpureum.*
14. *Auricularia* (reconstructed: diagrammatic).
15. *Septobasidium.*
16–18. *Ustilago* (reconstructed: diagrammatic).
19. *Corticium (Botryodea) calospora* sp. ined.
20. *Corticium sterigmaticum.*
21. *Botryobasidium coronatum.*
22. *Hymeniales.* "Typical" homobasidium (diagrammatic).
23–25. *Corticium (Urnigera) subtrigonospermum* sp. ined.
26. *Aleurodiscus* (diagrammatic).
27, 28. *Melanogaster variegatus.* Immature and mature basidia.
29. *Lycoperdon.*

Figs. 1–6, 9, 10, 12, 13, 19–21, 23–25, 27, 28 are redrawn from camera lucida drawings by the author; fig. 7 is redrawn from a drawing by Martin, 8 after Fisher, 15 from a figure by Coker, 16, 17 after Harper, 29 after Coker & Couch. Most of the figures have been altered in a greater or lesser degree, either after examination of a greater range of objects or, with the borrowed figures, according to other figures. It is not intended that any figure should be a representation of a particular object, but of the structure typical of the taxonomic unit—genus or species—in question.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and

John Britts Owen

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PREFACE

Although cephalopods are abundant in the Pennsylvanian strata of Oklahoma and Texas, they are relatively rare in equivalent beds to the north of there. The numerous well-preserved specimens described in this report represent the fruits of more than eleven years of diligent collecting on the part of the junior author, and it is very doubtful if a comparable assemblage will ever be got together again. A surprisingly large variety of ammonoids was found in association with these nautiloids, and a study of them will be undertaken in the near future.

An extensive discussion of the morphology and terminology of the nautiloid shell has recently been published by the senior author, in conjunction with Professors C. O. Dunbar and G. E. Condra, in Bulletin 9 of the Nebraska Geological Survey. In that volume most of the genera of Pennsylvania nautiloid cephalopods are diagnosed and the species referable to each are listed. There is, of course, no need for that work to be duplicated here, and the reader is referred to the Nebraska bulletin for a more detailed explanation of nautiloid terminology and nomenclature than is given in the present study.

The authors are under obligation to Professor C. O. Dunbar of Yale University, Professor H. G. Walter of Utah State Agricultural College, and Mr. Joe Harner of Nevada, Missouri, for the loan of specimens studied during the preparation of this report.

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April 25, 1934

CONTENTS

Cherokee Nautiloids of the Northern Mid-Continent Region

INTRODUCTION

In the northern part of the Mid-Continent region, that is, in Iowa, Missouri, and Kansas, the strata which are called Cherokee are more or less of a stratigraphic unit and are generally regarded as constituting a formation. However, in the southern part of the Mid-Continent region chronologically equivalent strata have been divided into several formations, and the term Cherokee is applied to the group. In this paper we will confine our attention largely to the nautiloids of the Cherokee formation and will discuss only incidentally those that occur in equivalent beds to the south.

THE CHEROKEE FORMATION

The Cherokee is the lowest formation in the Pennsylvanian system in the northern portion of the Mid-Continent region. It outcrops in a long, relatively narrow belt extending from southeastern Iowa in a southwesterly direction across Missouri to southeastern Kansas and northeastern Oklahoma as far as the Arkansas River. Its thickness varies greatly but in general it thins to the northeast; locally in Oklahoma it is well over 1000 feet thick, in southeastern Kansas and in Missouri it has an average thickness of about 300 or 400 feet, but in southeastern Iowa it averages only about 200 feet. Lithologically the formation consists largely of shale but there is considerable variation both vertically and laterally within it; it contains considerable quantities of sandstone and limestone, and coal beds are scattered throughout its entire vertical and horizontal extent. In all but the lower portions of the formation, the limestone and the coal members are fairly continuous over large areas and they are therefore good horizon markers. The coal beds are of very great economic importance, and in southeastern Kansas and adjacent portions of Oklahoma, the more or less irregular beds of sandstone in the Cherokee have yielded considerable quantities of oil and gas.

Since most of the cephalopods described in this report came from Henry County, Missouri, the following generalized section of the Cherokee formation in that county will be helpful:

GENERALIZED SECTION OF THE CHEROKEE SHALE IN HENRY COUNTY, MISSOURI
(After Hinds and Greene[1])

		Feet
1.	Shale, light at top, black and slaty at base; bears large concretions	4
2.	Coal (Lexington)	1
3.	Clay and shale	9
4.	Limestone	2
5.	Shale and sandstone; with thin and irregular coal bed at base; 25 to 50 feet thick	35
6.	Limestone, gray; weathers rough on top; in places a foot or more of blue limestone at base; absent in places, 15 feet thick in others	8
7.	Shale, slaty	4½
8.	Coal (Mulky), absent in places	1
9.	Shale, blue	30
10.	Coal (Bevier), absent in places	1½
11.	Clay, shale, and sandstone; 3 to 12 feet thick	8
12.	Limestone, variable; absent in places, 6 feet thick in others	3
13.	Shale, light at top, black and slaty below; locally with large concretions; absent in places	5
14.	Coal (Tebo), absent in places	2
15.	Shale and sandstone, with basins of coal distributed irregularly both stratigraphically and geographically, including the Mammoth coal bed 40 feet below the Tebo horizon, and the Jordan coal, 70-100 feet below the same horizon	80-230
16.	Mississippian limestone	—

THE FAUNA OF THE CHEROKEE FORMATION

The Cherokee is not as abundantly fossiliferous as are some of the divisions of the Pennsylvanian system in the Mid-Continent region but it has yielded quite an assemblage of foraminifera, brachiopods, bryozoans, mollusks, and ostracodes, and a few corals, crinoids, trilobites, etc. Cephalopods are not as abundant in the northern part of the Mid-Continent region as they are farther south, and the large collection which we are studying represents the results of more than eleven years of patient, intensive collecting

[1] Henry Hinds and F. C. Greene: The stratigraphy of the Pennsylvanian series in Missouri. Missouri Bur. Geol. and Mines, vol. 13, ser. 2, 1915, p. 47.

in west-central Missouri in and around the numerous strip pits which are dug to obtain coal—only a very few of the specimens came from natural exposures. Most of them came from large black calcareous nodules or concretions which occur in the shales that immediately overlie the Tebo and the Lexington coals; the shales which surround these concretions are also fossiliferous but the fossils in them are so fragile that it is rarely possible to collect large specimens. We have one specimen (*Temnocheilus* cf. *T. harneri*) from a dark-gray calcareous concretion immediately above an unnamed local coal which occurs some 15 feet below the Lexington coal, two specimens (*Metacoceras* spp.) from brownish-black ferruginous lenses immediately above the Jordan coal, and representatives of seven species from a local blue-to-drab jointed limestone, some 3½ feet thick, which occurs about 10-15 feet below the Jordan coal and immediately overlies an unnamed local coal. Also, through the courtesy of Mr. Joe Harner of Nevada, Missouri, we are able to study two specimens from immediately above the Rich Hill coal (near the middle of the Cherokee) in Vernon County, Missouri; and in 1891 Hyatt[2] described a small collection of nautiloids from immediately above the Lexington coal near Oswego, Kansas—we are bringing together in this report all of the available information in regard to these Cherokee specimens described by Hyatt. The known stratigraphic distribution of nautiloids within the Cherokee formation is portrayed clearly by the accompanying table (page 194).

So many of these species are known from only one specimen that we must regard our knowledge of the distribution of nautiloids within the Cherokee as very imperfect, and after a detailed study of all of the available material we are of the opinion that at least as far as nautiloids are concerned, the fauna of the Cherokee should be considered as a unit and not as a number of separate faunules each of which is indicative of a limited horizon within the formation. Nevertheless, our collections indicate rather strongly that *Brachycycloceras longulum* and *Metacoceras biseriatum* probably do not occur in the lower part of the Cherokee, that is, below the Tebo coal horizon, and *Parametacoceras bellatulum* probably does not occur below the uppermost portion of the Cherokee, that is, below the Lexington coal horizon. Some of the species that occur in the

[2] Alpheus Hyatt: Carboniferous cephalopods. Texas Geol. Survey Ann. Rep. 2, 1891, pp. 327-356.

TABLE SHOWING KNOWN STRATIGRAPHIC RANGE AND DISTRIBUTION OF NAUTILOID SPECIES WITHIN THE CHEROKEE FORMATION

	Exact horizon uncertain	10-15 feet below Jordan coal	Jordan coal horizon	Tebo coal horizon	Rich Hill coal horizon	15 feet below Lexington coal	Lexington coal horizon
Pseudorthoceras knoxense				x			
Poterioceras bransoni				x			x
Poterioceras mehli							x
Mooreoceras normale		x		x			x
Mooreoceras normale uniconstrictum				x			
Bactrites? cherokeensis		x					
Brachycycloceras longulum				x			x
Ephippioceras ferratum		x		x			
Megaglossoceras pristinum		x					
Coloceras missouriense	x						
Coloceras sp.				x			
Coloceras sp.							x
Knightoceras missouriense				x			
Temnocheilus harneri				x	x		
Temnocheilus cf. T. harneri						x	
Temnocheilus sp.							x
Metacoceras mutabile		x		x			x
Metacoceras biseriatum				x			x
Metacoceras sp.				x			
Metacoceras 2 sp.			x				
Parametacoceras bellatulum							x
Parametacoceras? crassum							x
Endolobus depressus							x
Endolobus sp.				x			
Domatoceras umbilicatum							x
Domatoceras williamsi		x		x	x		
Solenochilus capax	x						
Solenochilus newloni							x
Solenochilus peculiare		x					

Cherokee, for example, *Pseudorthoceras knoxense, Mooreoceras normale,* and *Ephippioceras ferratum,* are known to range throughout much of the Pennsylvania system.

COMPARISON WITH OTHER FAUNAS

Although several of the formations in Oklahoma, Arkansas, and Texas that are stratigraphically equivalent to the Cherokee formation have yielded a few fragmentary nautiloids, no nautiloid fauna is known from the southern part of the Mid-Continent region that is comparable to the one described in this report, and none of the faunas known from the lower Pennsylvanian of Illinois or the eastern part of the United States contain many similar nautiloids. However, Tzwetaev[3] has described a nautiloid fauna from the Upper Carboniferous of central Russia that contains striking counterparts of several of the representatives of the Cherokee species. This Russian fauna was collected largely from the oölite near the village of Dewiatowo (province of Moscow), the Fusulina limestone near the village of Miatschkowo (province of Moscow), and the Fusulina limestone near the Matkosersky Canal (province of Olonets); according to Tzwetaev all three of these represent the same stratigraphic horizon and most of the species described by her are known to occur in at least two of these three localities. Almost all of the nautiloid genera represented in this Russian fauna are represented also in the Cherokee fauna we are studying, and the following specific similarities are worthy of note:

SPECIES FROM THE CHEROKEE OF MISSOURI	CORRESPONDING SPECIES FROM THE UPPER CARBONIFEROUS OF CENTRAL RUSSIA[4]
Mooreoceras normale	*Mooreoceras laterale?*
Ephippioceras ferratum	*Ephippioceras bilobatum?*
Coloceras sp.	*Coloceras globatum?*
Knightoceras missouriense	*Knightoceras subcariniferum*
Temnocheilus harneri	*Temnocheilus acanthicus*
Parametacoceras bellatulum	*Parametacoceras nikitini*
Endolobus sp.	*Endolobus? atuberculatus*
Domatoceras williamsi	*Domatoceras mosquense*

[3] Marie Tzwetaev: Cephalopodes de la section supérieure du calcaire carbonifère de la Russie centrale. Mém. du Comité Géol., vol. 5, no. 3, 1888, pp. 1-58, pls. 1-6.

[4] *Parametacoceras nikitini* is known from only the Upper Carboniferous limestone near the village of Gjél (province of Moscow). All of the other Russian species listed except *Temnocheilus acanthicus* are known to occur in the Dewiatowo oölite. *Mooreoceras laterale?*, *Ephippioceras bilobatum?*, and *Domatoceras mosquense* occur also with *Temnocheilus acanthicus* in the Fusulina limestone near Miatschkowo; and *Ephippioceras bilobatum?*, *Temnocheilus acanthicus*, and *Domatoceras mosquense* occur also in the Fusulina limestone near the Matkosersky Canal.

It should also be noted in this connection that the type of the genus *Fusulina, F. cylindrica* Fischer-de-Waldheim, was originally described from the Fusulina limestone near Miatschkowo, and the genus *Fusulina* s. s. is not known to occur above the Des Moines series in North America. Furthermore, as has recently been noted by Skinner,[5] *F. leei* Skinner of the mid-portion of the Cherokee group (Bluejacket sandstone) of Oklahoma is very closely similar to *F. cylindrica* of Miatschkowo, and these two species certainly are not greatly different in age. These facts have led us to the conclusion that the Fusulina limestone and the Dewiatowo oölite of central Russia are to be correlated with the Cherokee formation of central North America.

DESCRIPTION OF GENERA AND SPECIES

Genus Pseudorthoceras Girty 1911

Pseudorthoceras knoxense (McChesney)

Plate VIII, figure 6

Although this species was founded[6] in 1860, it was entirely overlooked until 1911, for the type specimens were very inadequately described and not illustrated and their location is not known. In 1911 Girty[7] resurrected this specific name, and in 1915 he[8] placed several names in its synonymy and published excellent figures and detailed descriptions of several specimens from the Wewoka formation of Oklahoma which he referred to this species. As a result, the present concept of the species rests almost entirely upon Girty's, rather than upon McChesney's, interpretation of the species. Unless McChesney's type specimens can be found, which seems unlikely, it will probably not be possible to determine whether or not Girty's specimens really represent this species. However, since the species represented by Girty's specimens is widespread geographically and

5 J. W. Skinner: Primitive fusulinids of the Mid-Continent region. Jour. Paleontology, vol. 5, 1931, p. 258.

6 J. H. McChesney: Descriptions of new species of fossils, from the Palaeozoic rocks of the Western States. Ext. Chicago Acad. Sci. Trans., vol. 1 (1859), 1860, p. 69. *Preprint.*

7 G. H. Girty: On some new genera and species of Pennsylvanian fossils from the Wewoka formation of Oklahoma. New York Acad. Sci. Annals, vol. 21, 1911, p. 143.

8 G. H. Girty: Fauna of the Wewoka formation of Oklahoma. U. S. Geol. Survey Bull. 544, 1915, pp. 227-234, pl. 27, figs. 1-6.

is abundant in many horizons in the Pennsylvanian system, and since McChesney's type specimens came from several horizons and localities in the Pennsylvanian of Illinois, it is probable that at least part of the original types were conspecific with Girty's specimens, and there is therefore no good reason not to use McChesney's name for this ubiquitous species—this usage might however be different to defend if it were seriously challenged.

This species was recently described in detail by Miller, Dunbar, and Condra[9] and its complete synonymy was listed; there is of course no need for us to duplicate this work. The most distinctive character of this species is the curved adapical portion of its conch, which is therefore a cyrtoceracone. Specimens of which the adapical portion of the conch is not preserved can be recognized by the peculiar, not-well-understood deposits in the camerae that have been described in detail by Girty and by Miller, Dunbar, and Condra. In the collection from the Cherokee of Missouri that we are studying, *P. knoxense* is associated with *Moorcoceras normale* M., D., and C.; fragmentary specimens of these two forms are easily differentiated without sectioning by the fact that in *P. knoxense* the siphuncle is central in position whereas in *M. normale* it is distinctly ventrad of the center, though it is not marginal.

Occurrence.—This species is widely distributed both geographically and stratigraphically in the Pennsylvanian of North America and it may occur in Europe also; stratigraphically it ranges from the Cherokee to the Wabaunsee and from the Bend to the Cisco; geographically it ranges from Pennsylvania on the east to Colorado on the west, and from Texas on the south to Michigan on the north. Recently Misch[10] and Heritsch[11] have referred to this species some specimens from the Upper Carboniferous near Nassfeld, in the Carnic Alps on the Austro-Italian border; in so far as we are able to tell from their descriptions and illustrations, these specimens do not differ essentially from the American forms. The specimen that

[9] A. K. Miller, C. O. Dunbar, and G. E. Condra: The nautiloid cephalopods of the Pennsylvanian system in the Mid-Continent region. Nebraska Geol. Survey Bull. 9, ser. 2, 1933, pp. 77-85, pl. 1, figs. 4-9.

[10] Peter Misch: *Pseudorthoceras Knoxense* Girty im Karnischen Oberkarbon. Naturwissenschaftlichen Verein für Steiermark Mitteilungen, Bd. 67, 1930, pp. 121-122, text fig.

[11] Franz Heritsch: Versteinerungen aus dem Karbon der Karawanken und Karnischen Alpen. Abhandl. Geol. Bundesanstalt, Bd. 23, Heft. 3, 1931, pp. 42-43, text fig. 8, pl. 1, figs. 3-7.

we are figuring (plate VIII, figure 6), which is the only one that we are positively identifying as *P. knoxense,* came from immediately above the Tebo coal member of the Cherokee in the Owen strip pits (sec. 29, T. 42 N., R. 26 W.), Henry County, Missouri.

Repository.—The specimen we are figuring is in the private collection of John Britts Owen, Clinton, Missouri, where it is numbered 518.

Genus Poterioceras M'Coy 1844

The type of this genus is *Orthocera fusiformis* Sowerby of the Lower Carboniferous of England and Ireland. Relatively recently Foerste[12] studied representatives of this species in the paleontological collections of the Museum of Comparative Zoölogy at Harvard University, and on the basis of them and the figures and descriptions that have been published he drew up the following up-to-date diagnosis of the genus:

"Conch a breviconic cyrtoceracone with circular cross-section, or slightly compressed laterally, with the ventral outline convex and the dorsal outline concave along the lower [adapical] part of the phragmacone and the upper [adoral] part of the living chamber, but convexly gibbous along the upper part of the phragmacone and the lower part of the living chamber. The living chamber is contracted toward the aperture and the outline of this aperture is slightly elliptical or circular, with no indication of a hyponomic sinus. If a trace of the latter is present, it has not been observed so far in any described species. The sutures of the septa are directly transverse along the greater part of the length of the phragmacone, but toward the living chamber these sutures rise distinctly from the ventral toward the dorsal side of the conch. The siphuncle is located a short distance ventrad of the center of the conch. According to Foord, it is marginal on the ventral side of the conch in the young, but recedes a little toward the center in the adult. Its segments present elongate elliptical outlines. No converging vertical [longitudinal] lamellae are present. [The type species has been described] from St. Doulagh's, [county of] Dublin, Ireland [and from England]; in the Lower Carboniferous limestone."

The forms described below coincide fairly well with this generic

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[12] Aug. F. Foerste: Actinosiphonate, trochoceroid and other cephalopods. Denison Univ. Bull., Jour. Sci. Lab., vol. 21, 1926, pp. 330-331.

diagnosis and they almost certainly should be referred to this genus. However, there is a slight but very distinct hyponomic sinus in the aperture of at least one of them, the adoral suture in both is very unusual, and the structure of the siphuncle is unfortunately not known. The Devonian and the Lower Carboniferous of both Europe and North America have yielded numerous forms that apparently represent this genus but none has heretofore been described from the Pennsylvanian.

POTERIOCERAS BRANSONI Miller and Owen, n. sp.

Plate VIII, figures 7-9; Plate IX, figure 1

Conch large, breviconic, cyrtoceraconic, subovoid, and subcircular in cross section. The holotype (plate IX, figure 1) is a nearly complete mature individual but it is not entirely removed from the matrix, the extreme adapical part of the conch is not preserved, and the extreme adoral part is not visible. The specimen is at least 270 mm. long and it attains a maximum diameter of at least 125 mm. The adapical portion of the phragmacone is curved exogastrically but the rest of the conch is nearly straight. The curved adapical portion of the conch is very rapidly expanded orad, but the rate of expansion of the conch gradually decreases adorally and in mature specimens the adoral half of the living chamber is contracted so that the maximum diameter of the conch is attained near the midlength of the living chamber—the living chamber is approximately as long as the phragmacone. The nature of the aperture is not ascertainable from the type material.

The extreme adapical portion of the conch is marked by very prominent transverse growth-lines or small lirae (plate VIII, figures 8, 9) but there is no indication of such on the other portions of any of the types. The internal mold is essentially smooth but along the venter there is a very small inconspicuous rounded ridge, and traces of fine longitudinal markings parallel to this ridge are discernible on the holotype. Also, on the adapical third of the living chamber of the holotype there appears to be a broad shallow rounded transverse dorso-lateral constriction comparable to that of *Poterioceras mehli,* described below; however, the dorsal and dorsolateral parts of the holotype are not well exposed and none of the paratypes represents the portion of the conch that would bear this constriction.

On the adapical portion of the phragmacone the sutures are straight and are directly transverse to the long axis of the conch but throughout most of the length of the phragmacone of large mature specimens like the holotype the sutures slope orad from the venter. The camerae are about one-sixth as long as wide but the adoral camerae of the holotype are much shorter than the preceding ones, indicating that this specimen represents a mature individual. The adoral suture of the holotype is very unusual; along the venter it is close and parallel to the preceding suture but a short distance (some 10 mm.) dorsad of there the adoral suture curves orad and along the ventro-lateral zone of the conch the adoral camera is about five times as long as it is along the venter—dorsad of there the adoral suture curves less strongly orad and it gradually approaches the preceding suture so that along the dorsum the adoral camera apparently is only about as long as it is along the venter.

The siphuncle is very small and is ventral but not marginal in position—unfortunately its structure can not be ascertained from the type material. At the adoral end of the phragmacone of one of the paratypes, a large mature specimen, where the conch is about 100 mm. in diameter, the siphuncle is about 18 mm. from the venter and is only about 3 mm. in diameter at its passage through a septum.

Remarks.—The peculiar shape of the adoral suture of mature representatives of this species differentiates them from all other described forms except *Poterioceras mehli,* described below, and presumably these two species are very closely related. They can be differentiated by the larger size, the contracted aperture, and the subovoid (rather than subconical) conch of the species described above. It is possible that some (or even all) of the small specimens that we are referring to this species may represent *P. mehli.* The fact that these two closely related forms are found associated together suggests the possibility that the difference between them may be due solely to sexual dimorphism. We have three mature representatives of *P. mehli* and they are all of essentially the same size, and we have two mature representatives of *P. bransoni* and they are also essentially equisized but they are much larger than *P. mehli.*

The specific name is given in honor of Professor E. B. Branson who has contributed extensively to our knowledge of the paleontology and stratigraphy of Missouri, as well as other regions.

Occurrence.—All of the types of this species came from the Cherokee of Missouri, and all but one of them, which came from Lafayette County (SE¼NW¼ sec. 15, T. 49 N., R. 25 W.), came from Henry County; all but two of them, which came from immediately above the Tebo coal, came from immediately above the Lexington coal. The specimens from the Tebo coal horizon came from the Borum strip pit (sec. 21, T. 41 N., R. 27 W.), and from the Carroll strip pits (sec. 9, T. 42 N., R. 25 W.); the specimen from the Borum pit is represented by figure 7 on plate VIII. The holotype and one of the paratypes came from the Lear strip pit (sec. 15, T. 43 N., R. 28 W.). The other four paratypes (including the specimens represented by figures 8 and 9 on plate VIII) came from the Ewing strip pits (sec. 36, T. 43 N., R. 28 W.).

Repository.—Private collection of John Britts Owen, Clinton, Missouri, Nos. 547 (holotype), 549 (pl. VIII, fig. 7), 550, 552, 554 (pl. VIII, fig. 8), 555 (pl. VIII, fig. 9), 556, 557.

POTERIOCERAS MEHLI Miller and Owen, n. sp.

Plate X, figures 1, 2

Conch moderately large, breviconic, subconical, and subcircular in cross section. This species is being based on three approximately equisized mature specimens, all of which represent most of the living chamber but only the adoral portion of the phragmacone. All three of the types are nearly straight but it seems probable that the adapical portion of the phragmacone of this species is comparable to that of *Poterioceras bransoni*, described above, and is therefore curved exogastrically. In mature specimens like the holotype (plate X, figures 1, 2) the living chamber is about 65 mm. long (measured along the lateral side of the conch), and it attains a maximum diameter near the aperture of about 90 mm.—the phragmacone was probably somewhat longer than the living chamber and apparently was rapidly expanded orad. The ventral side of the living chamber is slightly flattened—in longitudinal profile the ventral side of the living chamber is slightly convex whereas the dorsal side is slightly concave. At least the adoral portion of the phragmacone is conical in shape.

The aperture is oblique to the long axis of the conch—it slopes apicad from the venter and the dorsal side of the living chamber is therefore very much shorter than the ventral side (see plate X,

figure 1). On the broad ventral side of the conch the aperture is nearly straight but is slightly concave as it is marked medianly by a very broad and shallow but nevertheless very distinct hyponomic sinus (see plate X, figure 2).

On the living chamber of large mature individuals the test is about 2 mm. thick and is marked externally by numerous very fine transverse growth-lines. The internal mold is essentially smooth but along the venter there is a very small rounded indistinct ridge and on either side of it there are traces of fine parallel markings. On the dorso-lateral portions of the internal mold of the living chamber there is a very prominent broad rounded transverse constriction which is about 20-25 mm. wide and about 3 mm. deep on large mature specimens like the holotype. This constriction becomes broader and shallower ventrally and it gradually disappears along the lateral sides of the conch. Dorsally it becomes shallower (but not broader) but it apparently continues across the dorsum. This constriction is not visible on specimens which retain the test and it apparently represents an internal thickening of the test.

At least on the adoral portion of the phragmacone the sutures are oblique to the long axis of the conch and slope orad from the venter. The camerae are about one-fifth or one-sixth as long as wide but in the adoral portion of the phragmacone of mature individuals the camerae are very short. As in *Poterioceras bransoni*, described above, the adoral suture of mature specimens is very unusual; along the ventral side of the conch it is straight and is parallel to the preceding suture, but about 10 mm. dorsad of the venter it curves abruptly orad and then gradually swings back apicad as it crosses the lateral and dorso-lateral sides of the conch—along the ventro-lateral zone of the conch the adoral camera is almost twice as long as it is along the venter, but along the dorsum it is slightly shorter than it is along the venter.

The siphuncle is small and is ventral but not marginal in position—unfortunately its structure can not be ascertained from any of the three type specimens. At the adoral end of the phragmacone of one of the paratypes, where the conch is about 80 mm. in diameter, the siphuncle is about 16 mm. from the venter and is about 2 mm. in diameter at its passage through a septum.

Remarks.—This species can be differentiated from all known forms except *Poterioceras bransoni*, described above, by the peculiar shape of its adoral suture and by the prominent transverse con-

strictions on the dorso-lateral portions of the living chamber. It differs from *P. bransoni* in that it is smaller and its conch is subconical rather than subovoid in shape as its living chamber is not contracted adorally.

The specific name is given in honor of our friend Professor M. G. Mehl—the senior author first became interested in paleontology in Professor Mehl's classroom.

Occurrence.—All three of the type specimens are from immediately above the Lexington coal member of the Cherokee, Henry County, Missouri. The holotype and one of the paratypes came from the Lear strip pit (sec. 15, T. 43 N., R. 28 W.); the other paratype came from the Bohler strip pit (sec. 22, T. 43 N., R. 28 W.).

Repository.—Private collection of John Britts Owen, Clinton, Missouri, Nos. 548 (holotype), 551, 553.

Genus MOOREOCERAS Miller, Dunbar, and Condra 1933

MOOREOCERAS NORMALE Miller, Dunbar, and Condra

Plate XI, figures 1-6

(?) 1892. *Orthoceras colletti* S. A. Miller, Indiana Dept. Geology and Nat. Resources Ann. Rep. 18, *Advance sheets*, pp. 67-68, pl. 10, fig. 1.
(?) 1894. *Orthoceras colletti* S. A. Miller, Indiana Dept. Geology and Nat. Resources Ann. Rep. 18, pp. 321-322, pl. 10, fig. 1.
1931. *Orthoceras colletti* Morse, Kentucky Geol. Survey, ser. 6, vol. 36, pp. 300, 325-326, pl. 54, figs. 1, 2.
1933. *Mooreoceras normale* Miller, Dunbar, and Condra, Nebraska Geol. Survey Bull. 9, ser. 2, pp. 87-89, pl. 2, figs. 5-7.

This species is abundant in the Cherokee of Missouri and the collection we are studying contains more than twenty-five representatives of it. However, since it was recently described in detail by Miller, Dunbar, and Condra, and since our specimens are in all respects typical, a study of them has yielded little that is new.

Our collection contains several exceptionally large specimèns; one of them (plate XI, figure 1) is about 40 cm. long but it is not complete apicad or orad and as it is septate throughout it represents only part of the phragmacone—it is about 52 mm. in diameter at its adoral end. Another specimen, which is somewhat fragmentary, presumably was much longer for it attains a maximum diameter of about 80 mm.—this specimen represents a gerontic individual for

the adoral camerae of its phragmacone are very short. The adoral 75 mm. of this large specimen represent living chamber, but the specimen is not complete adorally and no portion of the aperture is retained. The rate of adoral expansion is constant throughout the entire length of all of the specimens we are referring to this species. On the adoral portion of the large specimen mentioned last the test apparently was about 4 mm. thick and was smooth externally. However, one small fragmentary specimen about 11 mm. in diameter, that we are tentatively referring to this species but which probably represents a distinct variety (or species), retains a small portion of the test and it is marked by prominent transverse lirae whereas the internal mold is smooth.

Occurrence.—This species is widely distributed in the Pennsylvanian system of the United States. Stratigraphically it is known to range from the Cherokee to the Wabaunsee. It has been found as far east as Kentucky, as far west as Colorado, as far north as Michigan, and as far south as Kansas. All of the specimens we are studying came from the Cherokee of Henry County, Missouri. Most of them came from immediately above the Tebo coal but some came from immediately above the Lexington coal and one specimen came from 10-15 feet below the Jordan coal immediately above an unnamed local coal.

Repository.—Private collection of John Britts Owen, Clinton, Missouri, Nos. 521-546. The figured specimens are numbered 521 (pl. XI, fig. 2), 522 (pl. XI, fig. 1), and 523 (pl XI, figs. 3-6); the large gerontic specimen mentioned above is numbered 545; and the small specimen with a lirate test is numbered 546.

MOOREOCERAS NORMALE UNICONSTRICTUM Miller and Owen, n. var.

Plate XI, figures 7, 8

We have two small specimens which are very similar to typical *M. normale* but differ from it in that they are small, although mature, and there is a very distinct transverse constriction on the living chamber of one of them—the living chamber of the other is not preserved. The specimen bearing the constriction is an internal mold representing much of the living chamber and the phragmacone, and we are designating it as the holotype of the new variety. It is about 41 mm. long but it is not complete adorally or adapically.

It is circular (or nearly so) in cross section and its diameter increases from a little more than 5 mm. near its adapical end to about 10 mm. near its adoral end. The internal mold is smooth but about 15 mm. orad of the junction of the phragmacone and the living chamber there is a very distinct broad shallow broadly rounded transverse constriction which is about 5 mm. wide and ½ mm. deep. The sutures are directly transverse and almost straight, but as in typical *M. normale* they are very slightly sinuous and on the holotype they form very slight ventral lobes. The length of the camerae is equal to about one-fourth the diameter of the conch but in both type specimens the adoral camera is slightly but distinctly shorter than the preceding one, which indicates that these specimens represent mature individuals.

The siphuncle is located about midway between the center and the venter. We have not been able to ascertain the structure of the siphuncle of the holotype, but that of the paratype is cyrtochoanitic in structure and its segments, though more or less pyriform, are nearly straight-sided throughout much of their length and in some cases they are very slightly concave laterally and resemble somewhat those of *Euloxoceras greenei* M., D., and C.[13]

Remarks.—This form differs from typical *M. normale* in that it is much smaller at maturity, there is a distinct transverse constriction near the adoral end of its living chamber, and its siphuncular segments are differently shaped. It is not improbable that this form should be regarded as a distinct species rather than as a variety of *M. normale.*

Occurrence.—Both types came from calcareous concretions immediately above the Tebo coal member of the Cherokee formation in the Shaw strip pit (sec. 23, T. 42 N., R. 26 W.), Henry County, Missouri.

Repository.—Private collection of John Britts Owen, Clinton, Missouri, No. 520 (holotype and paratype).

[13] A. K. Miller, C. O. Dunbar, and G. E. Condra: The nautiloid cephalopods of the Pennsylvanian system in the Mid-Continent region. Nebraska Geol. Survey Bull. 9, ser. 2, 1933, pl. 1, fig. 14.

Genus BACTRITES Sandberger 1843

BACTRITES? CHEROKEENSIS Miller and Owen, n. sp.

Plate VIII, figure 5; Plate X, figure 3

Conch long, slender, straight, gradually expanded orad, and broadly elliptical in cross section as it is slightly compressed laterally. The holotype and only known representative of this species is an internal mold of four (and a part of a fifth) camerae of the phragmacone; it is about 85 mm. long and at its adapical end its two diameters measure about 30 mm. and 27 mm. (estimated), whereas at its adoral end these two diameters measure about 41 mm. and 37 mm., respectively.

Surface of holotype is marked by traces of growth-lines which are parallel to the sutures and by faint traces of longitudinal lirae. Camerae long and their length is equal to about one-half the longer (dorso-ventral) diameter of the conch. Sutures of holotype are not quite perpendicular to the long axis of the conch but this is probably due to a slight amount of distortion that the specimen has obviously undergone during preservation. The ventral portion (siphuncular side) of the holotype is not well preserved and it is therefore impossible to tell whether or not there is a small ventral lobe in the sutures, but on the ventro-lateral, lateral, dorso-lateral, and dorsal sides of the conch the sutures are straight. Septa moderately convex apicad. Siphuncle small in size and ventral and marginal in position—it was in contact with the wall of the phragmacone or very nearly so. Segments of siphuncle are essentially cylindrical in shape and siphuncle is orthochoanitic in structure. At adapical end of holotype siphuncle is about 3 mm. in diameter.

Remarks.—We are very uncertain about the generic affinities of this form. Long straight cephalopods with nearly straight sutures and small marginal siphuncles first appear in the Lower Ordovician of Bohemia—these early forms are referred to the genus *Eobactrites.* No similar forms are known from the Silurian but a variety of forms has been described from the Devonian of both Europe and North America and referred to the genus *Bactrites.* The Mississippian of Arkansas and Oklahoma, the Pennsylvanian of Texas and Peru, and the Permian of Sicily and Mexico has yielded comparable forms—these have been regarded as nautiloids by some authors and referred to the genus *Orthoceras,* whereas other authors have re-

garded them as ammonoids and referred them to the genus *Bactrites*. In 1909 Girty[14] called attention to the uncertainty in regard to the generic affinities of these Carboniferous forms, and in 1928 Thomas[15] referred to *Orthoceras* one of them that had heretofore always been referred to *Bactrites*—two years later Miller[16] referred it back to *Bactrites*. Recently Schindewolf[17] has expressed uncertainty in regard to the generic affinities of the Carboniferous forms under consideration, and Spath[18] has gone so far as to refer to the Nautiloidea all of the species, Ordovician, Devonian, and Carboniferous, that have been referred to *Bactrites* except those that had been removed to *Lobobactrites*. The form described above certainly seems to us to be a nautiloid and not an ammonoid, but we are very uncertain in regard to its relation to *Bactrites subconicus* Sandberger of the Wissenbach shale (Middle Devonian) of Germany, which is the genotype of *Bactrites*—if our species is not congeneric with that form, it represents an unnamed genus for it is not closely related to the genotype of either *Orthoceras* or *Orthoceratites*. It is however closely related to *Bactrites? carbonarius* Smith of the Mississippian of Arkansas and possibly the Upper Carboniferous of Peru, *B.? quadrilineatus* Girty of the Mississippian of Oklahoma, *B.? smithianus* Girty of the Mississippian of Arkansas and Oklahoma, *B.? postremus* Miller of the Pennsylvanian of western Texas, and *B.? adrianense* Gemmellaro and *B.? paternoi* Gemmellaro of the Permian of Sicily—its large size and elliptical conch and the relative length of its camerae serve to distinguish it from these forms.

Occurrence.—Holotype and only known representative of this species came from an unnamed limestone member of the Cherokee formation, 10-15 feet below the Jordan coal, England strip pit (sec. 17, T. 41 N., R. 25 W.), Henry County, Missouri.

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14 G. H. Girty: The fauna of the Caney shale of Oklahoma. U. S. Geol. Survey Bull. 377, 1909, p. 52.

15 H. Dighton Thomas: An Upper Carboniferous fauna from the Amotape Mountains, north-western Peru. Geological Magazine, vol. 65, 1928, p. 290.

16 A. K. Miller: A new ammonoid fauna of Late Paleozoic age from western Texas. Jour. Pal., vol. 4, 1930, p. 389.

17 O. H. Schindewolf: Vergleichende Morphologie und Phylogenie der Anfangskammern tetrabranchiater Cephalopoden. Preuss. geol. Landesanstalt Abhandl., N. F., Heft 148, 1933, pp. 69, 73.

18 L. F. Spath: The evolution of the Cephalopoda. Biological Reviews, vol. 8, no. 4, 1933, pp. 445-447, 459.

Repository.—Private collection of John Britts Owen, Clinton, Missouri, No. 519.

Genus BRACHYCYCLOCERAS Miller, Dunbar, and Condra 1933

BRACHYCYCLOCERAS LONGULUM Miller and Owen, n. sp.

Plate VIII, figures 1-4

Conch long, slender, straight, rather gradually expanded orad, and circular in cross section. The longest of the types is only about 45 mm. long, but is incomplete both orad and apicad and is rather small—some of the types attain a diameter of as much as fifty per cent more than that of this specimen. None of the types is complete apicad, but their rate of adoral expansion indicates an apical angle of about 10 or 11 degrees. There is no indication on any of the types of an abrupt expansion of the adoral end of the living chamber which is so conspicuous in some of the members of this genus.

Surface of conch marked throughout by abrupt prominent narrow rounded annulations which are directly transverse to the long axis of the conch but are deflected slightly apicad near the center of the lateral sides of the conch. The size and spacing of these annulations vary somewhat in different specimens and in different parts of the same specimen but four to six of them occur in a length equal to the diameter of the conch and even on the adoral end of the largest of the types they are distinctly less than 1 mm. high and less than 1 mm. wide. The spaces between the annulations are relatively broad and flat. Both the annulations and the intervening flat spaces are very finely lirate, and the lirae are parallel to the annulations and like them are deflected slightly apicad on the lateral sides of the conch. The annulations, but not the lirae, are very distinct on the internal mold but they are not as prominent there as they are on the exterior of the test.

Sutures are directly transverse but they appear to be somewhat sinuous and to form broad shallow broadly rounded saddles on the lateral sides of the conch and similar lobes on the dorsal and ventral sides. The length of the camerae can unfortunately not be determined from the type material. The septa are rather strongly convex apicad and the amount of their curvature is equal to about one-third their diameter. The siphuncle is small and it is located about midway between the center and the venter; presumably it is

orthochoanitic in structure as is that of other representatives of this genus, but its structure can not be ascertained from any of the types.

Remarks.—The relatively long slender form of the conch of this species serves to distinguish it from the other known representatives of the genus. Also, its conch apparently is not flared near the aperture as is that of *Brachycycloceras crebricinctum* (Girty) and *B. kentuckiense* M., D., and C., and in *B. normale* M., D., and C. the annulations are farther apart. Unfortunately the relationship between this species and "*Orthoceras rushensis*" McChesney of the Pennsylvanian of Indiana and Illinois can not be determined for the types of that species, which were never illustrated, have been lost and the original description of the species is very brief and generalized.

Occurrence.—All of the types of this species came from the Cherokee, and all but one came from Henry County, Missouri—the remaining one came from above the Lexington coal (just under the Fort Scott limestone), about 1¾ miles southeast of Leeton, Johnson County, Missouri. Four of the specimens from Henry County, including one of the figured types (plate VIII, figures 2-4) came from immediately above the Lexington coal in the Howell strip pit (sec. 19, T. 42 N., R. 25 W.). The rest of the types (four specimens) came from immediately above the Tebo coal—one of them (plate VIII, figure 1) came from the Carroll strip pits (sec. 9, T. 42 N., R. 25 W.); another came from a strip pit about ¼ mile north of Montrose, Missiuri, a third came from the Russell strip pit (sec. 32, T. 42 N., R. 26 W.); and the fourth came from the Bradley strip pits (sec. 17, T. 43 N., R. 24 W.).

Repository.—Private collection of John Britts Owen, Clinton, Missouri, Nos. 511-517 (cotypes); the figured specimens are numbered 512 (plate VIII, figure 1) and 515 (plate VIII, figures 2-4).

Genus Ephippioceras Hyatt 1883

Ephippioceras ferratum (Cox)

Plate XII, figures 3, 4; Text figures 1A, 1B

Recently Miller, Dunbar, and Condra[19] described this species in detail, discussed its affinities at some length, and listed its complete

[19] Op. cit., pp. 114-118, pl. 3, figs. 14-17.

synonymy—there is of course no need for us to duplicate this work. However, the collection we are studying contains ten representatives of this species and although they are not entirely complete they are well preserved and a detailed study of them has yielded exact data in regard to the surface ornamentation of the conch and the nature of the internal sutures, which heretofore were known in only a general way.

Two of the small specimens, early mature individuals, retain portions of the test and fortunately they are exceptionally well preserved. The exterior of the conch is marked by numerous fine transverse growth-lines and by much finer and more numerous longitudinal lirae which give it a finely reticulate surface. Each growth-line forms a broad shallow broadly rounded salient on the lateral sides of the conch and a similar but more narrowly rounded sinus on the ventral side. Certain of the growth-lines are more prominent than the others and these prominent growth-lines are somewhat regularly spaced, but their spacing is not nearly as regular as it is stated to be by Sayre[20] on conspecific specimens from the Westerville limestone (Kansas City group) of Kansas City, Missouri, and Turner, Kansas. The longitudinal lirae, though in general straight, are very finely sinuous.

One of the specimens we are studying has been prepared in such a way that its internal as well as its external sutures are visible. As indicated by the accompanying diagram (text figure 1A, page 213), each external suture consists of a broad deep narrowly rounded depressed-V-shaped ventral saddle and on either side of it a very broad shallow broadly rounded asymmetrical lateral lobe and a smaller rounded dorso-lateral saddle which centers on the umbilical shoulder and is followed by a broad very shallow broadly rounded lobe on the umbilical wall. Each internal suture consists of a broad broadly rounded dorsal saddle and on either side of it a similar but narrower lateral lobe and a small angular saddle that centers on the umbilical seam and is followed by the lobe on the umbilical wall. In general the septa are moderately convex adapically but they are marked medianly by a prominent dorso-ventral fold.

Occurrence.—This species is widely distributed in the Pennsyl-

[20] A. N. Sayre: The fauna of the Drum limestone of Kansas and western Missouri. Univ. of Kansas Sci. Bull., vol. 19, pt. 2, 1930, p. 154. Reprinted as Kansas Geol. Survey Bull. 17, 1930.

vanian of North America; it is known to range from Kentucky on the east to Nebraska on the west, and stratigraphically from the base of the Cherokee to the top of the Lansing. The collection we are studying contains ten representatives of this species all of which came from the Cherokee of Henry County, Missouri; nine of them came from immediately above the Tebo coal, whereas the tenth came from an unnamed limestone 10-15 feet below the Jordan coal. The smaller of the figured specimens (plate XII, figure 3), came from the Russell strip pit (sec. 32, T. 42 N., R. 26 W.); the larger of the figured specimens (plate XII, figure 4; text figures 1A, 1B) and one of the specimens which retain the surface marking of the test came from the Tillman strip pit (NE¼NE¼ sec. 23, T. 42 N., R. 26 W.); the other specimen which retains the surface markings of the test came from the Vansant strip pits (sec. 22, T. 41 N., R. 27 W.); one of the other specimens came from the Carroll strip pits (sec. 9, T. 42 N., R. 25 W.); three of the remaining specimens came from the Bradley strip pits (sec. 17, T. 43 N., R. 24 W.); the other specimen from above the Tebo coal came from the J. H. Britts strip pit (sec. 29, T. 42 N., R. 26 W.); and the single specimen from below the Jordan coal came from the England strip pit (sec. 17, T. 41 N., R. 25 W.).

Repository.—All of the specimens being studied by us are in the private collection of John Britts Owen, Clinton, Missouri, where they are numbered 501-506 and 509, 510. The figured specimens are numbered 501 (plate XII; figure 3) and 502 (plate XII, figure 4; text figures 1A, 1B); the specimens retaining surface markings of the test are numbered 503 (Tillman strip pit) and 504 (Vansant pits); the single specimen from below the Jordan coal is numbered 510.

Genus MEGAGLOSSOCERAS Miller, Dunbar, and Condra 1933

Only four species have heretofore been referred to this genus; these are *Megaglossoceras montgomeryense* (Worthen) of the McLeansboro formation of Illinois (the genotype), *M. magnum* M., D., and C. of the lower Fort Scott limestone (basal Marmaton) of Kansas[21], *M. rectilaterale* M., D., and C. of the Argentine limestone

[21] The exact horizon and locality from which the holotype of this species, which was originally referred to *Ephippioceras divisum* (White and St. John), came are given by Beede and Rogers in Kansas University Science Bulletin, vol. 2, 1904, pp. 463, 465.

(Lansing) of Nebraska, and *M. johnsoni* M., D., and C. of the Lower Pennsylvanian of Colorado. We are describing below an additional species, *M. pristinum,* from the Cherokee of Missouri, and also it seems to us that *Nautilus gilpini* Swallow may represent this genus. The type specimen of *N. gilpini,* which was only briefly described, was never figured, and was lost in the fire at the University of Missouri in 1892, came from Wayne City, an abandoned town located on the Missouri River in Jackson County, Missouri, about four miles north of Independence, Missouri[22]—presumably the specimen came from the Kansas City group but it may have come from the Bronson.

A detailed study of the specimen described below as *Megaglossoceras pristinum,* n. sp., has yielded the first reliable information in regard to the internal structures of the conch in this genus that has been available. Furthermore, since this specimen is a very primitive representative of the genus and is more or less intermediate between typical *Ephippioceras* and typical *Megaglossoceras,* it enables us to get a clearer concept of the relation between these two genera.

The septa in this genus are moderately convex adapically but they are marked medianly by a prominent dorso-ventral fold. Each complete suture consists of a total of six saddles and six lobes (see text figure 1C). Each external suture consists of a very prominent rounded more or less tongue-shaped ventral saddle and on either side of it a broad shallow rounded asymmetrical lateral lobe and a broad very shallow narrowly rounded or subangular dorso-lateral saddle which centers on the umbilical shoulder and which is followed by a broad very shallow broadly rounded lobe on the umbilical wall. Each internal suture consists of a broad rounded prominent dorsal saddle and on either side of it a similar but smaller and shallower lateral lobe and a low broad angular saddle that centers on the umbilical seam and is followed by the lobe on the umbilical wall.

The siphuncle is subcentral in position, moderately small in size, and orthochoanitic in structure—its segments are not expanded appreciably within the camerae and, though slightly curved, are essentially cylindrical in shape.

Miller, Dunbar, and Condra[23] state that *Megaglossoceras* and

[22] This information in regard to Wayne City was furnished us by Mr. Floyd C. Shoemaker, Secretary of the State Historical Society of Missouri.

[23] Op. cit., p. 119.

Ephippioceras probably descended from a common ancestor. This view was based on the assumption that *Megaglossoceras magnum* M., D., and C. of the lower Fort Scott limestone (basal Marmaton) of Kansas is an exceedingly primitive representative of the genus and that it developed from a nautiloid with straight sutures by the formation of a broad shallow broadly rounded ventral saddle in its sutures. The specimen described below as *M. pristinum* also appears to be a very primitive representative of this genus—its umbilical shoulders, like those of *M. magnum,* are rounded rather than angular, as is typical for this genus, and the ventral saddle in its sutures is not nearly as straight sided as it is in *M. johnsoni* M., D., and C., for example. The form of its conch and the shape of its sutures (with the exception of the ventral saddle) are so strikingly similar to those of typical representatives of *Ephippioceras* (see text figures 1A-1D) that it seems very probable that this form developed from some representative of the genus *Ephippioceras* by a broadening and deepening of the ventral saddles of the sutures—although in so far as is now known, *Ephippioceras* is limited to the

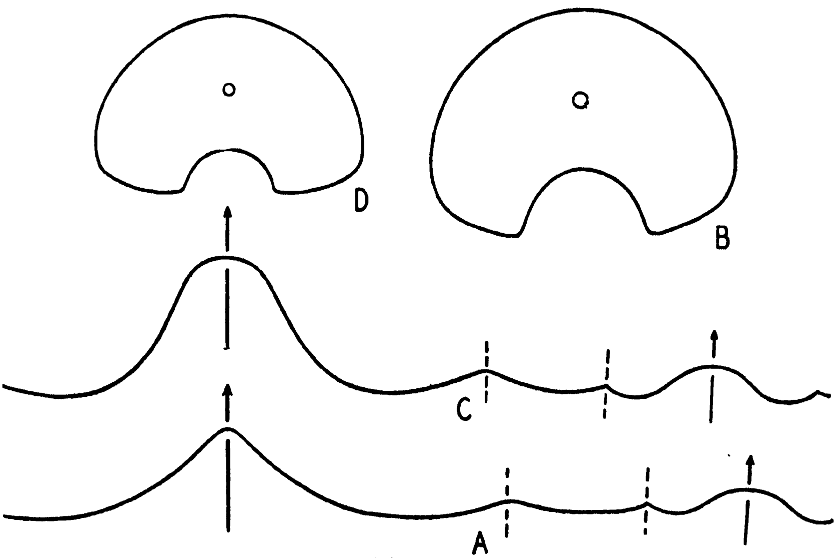

Figure 1

Figure 1.—Diagrammatic representations of
A,B—suture and cross section of conch of an early mature representative of *Ephippioceras ferratum* (Cox), x 2;
C,D—suture and cross section of conch of holotype of *Megaglossoceras pristinum*, n. sp., x 1.

Pennsylvanian in North America, in Europe it is well represented in the Lower Carboniferous, so as far as chronology is concerned this phylogeny is possible. If this view is correct, then *M. magnum* is either a degenerate form (for the ventral saddle in its sutures is shallower than is that of typical *Ephippioceras*, and the cross section of the conch is considerably different), or it represents an independent development and is therefore not closely related to *M. pristinum*—at present we are inclined to favor the latter view but more representatives of this group will have to be collected and studied before any reliable conclusions as to its phylogenetic development can be reached.

MEGAGLOSSOCERAS PRISTINUM Miller and Owen, n. sp.

Plate XII, figures 1, 2; Text figures 1C, 1D

Form subglobose. Conch nautiliconic, rapidly expanded orad, and apparently consists of about two or three volutions. Whorls reniform in cross section, depressed dorso-ventrally, broadly rounded ventrally and laterally, rather narrowly rounded dorso-laterally, and impressed dorsally (see text figure 1D). Conch is about two-thirds as high as wide and is impressed dorsally to about one-fourth its height; impressed zone is about twice as wide as high. Living chamber at least one-half a volution in length. Aperture marked ventrally by a broad shallow rounded hyponomic sinus. Umbilicus small but deep; umbilical shoulders rounded; umbilical walls steep and nearly straight but slightly convex.

The holotype and only known representative of this species is an internal mold that represents much of the phragmacone and the living chamber. Its maximum diameter, measured from the adoral end of the preserved part of the venter across the umbilicus to the opposite side of the specimen, measures about 105 mm.; the diameter at right angles to this and across the umbilicus measures about 82 mm. The preserved part of the conch attains a maximum width of about 90 mm. (estimated) and a maximum height of about 57 mm.; at the adapical end of the outer volution the conch is only about 32 mm. wide (estimated) and about 21 mm. high. Faint traces of the growth-lines on the adapical portion of the living chamber of the holotype indicate that the hyponomic sinus there was about 15 mm. deep. The umbilicus appears to have attained a maximum diameter of about 20 mm.

The surface of the internal mold is essentially smooth and there

is no trace of low broad transverse annulations which occur in some other representatives of this genus. There is, however, a small rounded ridge or raised line along the venter—this of course represents a stria on the inside of the conch. Each external suture consists of a very prominent rounded more or less tongue-shaped ventral saddle and on either side of it a broad shallow broadly rounded asymmetrical lateral lobe and a broad very shallow rather narrowly rounded dorso-lateral saddle which centers on the umbilical shoulder and which is followed by a broad very shallow broadly rounded lobe on the umbilical wall (see text figure 1C). Each internal suture consists of a broad rounded prominent dorsal saddle and on either side of it a similar but smaller and shallower lateral lobe and a low broad angular saddle that centers on the umbilical seam and is followed by the lobe on the umbilical wall. The septa are moderately convex adapically but they are marked medianly by a prominent dorso-ventral fold.

The siphuncle is subcentral and is rather small. Its segments are not expanded appreciably within the camerae and, though slightly curved, are essentially cylindrical—these facts indicate that the siphuncle is orthochoanitic in structure but we have not been able to determine the relative lengths of the septal necks and the connecting rings. Near the adoral end of the phragmacone of the holotype, where the conch is about 30 mm. high, the siphuncle is about 3½ mm. in diameter and its center is about 13 mm. from the venter.

Remarks.—This species is so distinct from all previously described forms that detailed comparisons would be superfluous. Its rounded umbilical shoulders serve to differentiate it from all known representatives of the genus *Megaglossoceras* except *M. magnum* M., D., and C. of the basal Marmaton near Oswego, Kansas. In that form the conch is large, low, and broad; the impressed zone is relatively shallow and its junctions with the dorsal side of the conch are broadly rounded rather than subangular; and there is a concave zone along the venter.

With the possible exception of *M. magnum, M. pristinum* is the most primitive representative of the genus *Megaglossoceras* known, and it is more or less intermediate between typical *Ephippioceras* and typical *Megaglossoceras;* however, the broadly rounded more or less tongue-shaped ventral saddles in its sutures indicate clearly

that its affinities are with *Megaglossoceras* rather than with *Ephippioceras.*

Occurrence.—Holotype and only known representative of this species came from an unnamed limestone member of the Cherokee formation 10-15 feet below the Jordan coal, England strip pit, sec. 17, T. 41 N., R. 25 W., Henry County, Missouri.

Repository.—Private collection of John Britts Owen, Clinton, Missouri, No. 507.

Genus COLOCERAS Hyatt 1893

COLOCERAS MISSOURIENSE (Swallow)

1858. *Nautilus Missouriensis* Swallow, St. Louis Acad. Sci. Trans., vol. 1, p. 198.

(?) 1884. *Nautilus Missouriensis?* C. A. White, Indiana Dept. Geol. and Nat. History, Ann. Rep. 13, pt. 2, p. 166, pl. 35, figs. 1, 2.

(?) 1893. *Nautilus* [*Coloceras?*] *missouriensis* Hyatt, Texas Geol. Survey Ann. Rep. 4, p. 453.

(?) 1894. *Nautilus missouriensis* Keyes, Missouri Geol. Survey, vol. 5 (Paleontology of Missouri, Part 2), p. 224, pl. 56, fig. 3.

(?) 1896. *Endolobus* (*Nautilus*) *missouriensis* J. P. Smith, Amer. Phil. Soc. Proc., vol. 35, pp. 252-253, pl. 21, figs. 1-3d. [Reprinted as Contributions to Biology from the Hopkins Seaside Laboratory, 9, 1896 (1897).]

1898. *Endolobus missouriensis* [part ?] Weller, U. S. Geol. Survey Bull. 153, p. 246.

(?) 1910. *Endobolus missouriensis* Raymond, Carnegie Museum Annals, vol. 7, p. 156.

1933. *Coloceras missovriense* Miller, Dunbar, and Condra, Nebraska Geol. Survey Bull. 9, ser. 2, pp. 131, 195.

This species was originally described by Swallow as follows:

> "*Shell* small, gibbous, smooth, somewhat flattened on the dorsal [ventral ?] margin; *aperture* reniform, transverse, slightly modified by the preceding whorl; *septa* sparingly concave, margin curved a little forward towards the inner border of the shell; *siphuncle* sub-central, a little nearer the ventral margin; *umbilicus* deep, partially closed.
>
> "Diameter, 0.65;[24] thickness of last whorl, 0.54; diameter of last whorl, 0.38.
>
> "State collection, from the Hydraulic Limestone, near the base of the Coal Measures in Boone County, where it is asso-

[24] The measurements in this paper are in inches.

ciated with *Productus splendens, P. Wabashensis, Chonetes mesoloba, Spirifer cameratus, S. lineatus* and *Naticopsis Pricei.*"

This description is entirely inadequate, it is not accompanied by an illustration, and the type specimen was lost in the fire at the University of Missouri in 1892. It is therefore very doubtful if the species can ever be recognized with certainty and even its generic affinities are somewhat in doubt. The specimens that C. A. White and J. P. Smith referred to this species are probably not all conspecific and, as recognized by both of these authors, it is very doubtful if any of their specimens represent Swallow's species. Keyes apparently referred to Swallow's specimen but he reproduced one of White's illustrations. Hyatt referred to White's illustrations. The collection we are studying contains two fragmentary representatives of *Coloceras* from the Cherokee of Missouri (which also yielded Swallow's type specimen) but in view of what has been said above it is not possible to determine whether or not either of these specimens represents Swallow's species.

Occurrence.—The holotype of this species came from the Cherokee of Boone County, Missouri. The specimen which C. A. White referred to this species came from the Pennsylvanian of Silverwood, Fountain County, Indiana, and the specimens which J. P. Smith referred to it came from the Lower Pennsylvanian (Atoka formation) of the center of N½ sec. 17, T. 5 N., R. 16 W., Conway County, Arkansas. Raymond lists this species from the Allegheny (Vanport limestone) of western Pennsylvania.

COLOCERAS spp.

Plate XVI, figure 3

The collection we are studying contains two specimens which apparently represent the genus *Coloceras* but which are so fragmentary that their specific affinities can not be determined satisfactorily. The sutures of both of these specimens are very slightly sinuous and they form very slight ventral and lateral lobes and similar ventro-lateral saddles; it is therefore quite possible that these specimens should be referred to the genus *Stearoceras* rather than to *Coloceras*—until more information is available in regard to *Coloceras hyatti* Miller, Dunbar, and Condra, the genotype of

Coloceras, it will not be possible to differentiate clearly between *Coloceras* and *Stearoceras.*

The conchs of both of our specimens are nautiliconic in their mode of growth, rapidly expanded orad, and therefore subglobular in shape. The internal mold is smooth with the exception of a very small indistinct ridge along the venter. The smaller of our specimens retains part of the test (or a replacement of it) and it is marked externally by numerous very fine growth-lines which indicate that the conch was marked ventrally by a broad deep rounded hyponomic sinus. The sutures of this specimen are more strongly sinuous than are those of the larger of our specimens (the figured specimen) and therefore it seems likely that we are dealing with two distinct species.

Occurrence.—Both of the specimens we are studying came from the Cherokee of Henry County, Missouri. The figured specimen came from immediately above the Tebo coal in the J. G. Turk strip pit (sec. 10, T. 41 N., R. 27 W.), whereas the other specimen came from immediately above the Lexington coal in the Ewing strip pit (sec. 36, T. 43 N., R. 28 W.).

Repository.—Private collection of John Britts Owen, Clinton, Missouri, Nos. 560 (figured specimen) and 561.

Genus KNIGHTOCERAS Miller and Owen, n. gen.

We have a single well-preserved specimen from the Cherokee of Missouri that apparently is not referable to any described genus and we here propose the generic name *Knightoceras* for it. This name is given in honor of Dr. J. Brookes Knight, in recognition of his excellent work on Missouri Pennsylvanian ostracodes and gastropods.

The new genus can be characterized as follows: Conch nautiliconic, subglobular, and rapidly expanded orad. Whorls strongly depressed dorso-ventrally and sublenticular in cross section as they are very broadly rounded ventrally and dorsally and are subangular laterally—the impressed zone along the dorsum is small and inconspicuous. Umbilicus very broad and deep. Prominent growth-lines indicate the presence of a broad deep rounded hyponomic sinus. Subangular lateral sides of conch (but not internal mold) projected to form a low and blunt but rather prominent carina. Each suture forms a very broad shallow broadly rounded

ventral lobe and on either side of it a shallow subangular lateral saddle which centers on the subangular lateral zone of the conch; on the broad dorso-lateral sides of the conch (the umbilical walls) the sutures are essentially straight but each forms a rather prominent rounded lobe as it crosses the dorsal impressed zone. Siphuncle small, subcentral in position, and orthochoanitic in structure.

Apparently *Nautilus subcariniferus* Tzwetaev of the Lower Pennsylvanian (Dewiatowo oölite) of central Russia in congeneric with *Knightoceras missouriense*, our genotype, but on the dorso-lateral sides of its conch (the umbilical walls) its sutures form broad shallow lobes. Tzwetaev[25] believed this Russian species to be closely related to *Nautilus cariniferus* J. de C. Sowerby of the Lower Carboniferous of Ireland and England, but in that form the dorso-lateral sides of the conch are concave rather than convex and the broad ventral side of the conch is marked by two longitudinal ridges.

This genus appears to be more closely related to *Vestinautilus* Ryckholt (of which *Coelonautilus* Foord is a synonym) than to any other described genus and it should be associated with it in the Triboloceratidae. The genotype of *Vestinautilus* is *Nautilus koninckii* d'Orbigny of the lower Mississippian (Tournacian) of Belgium; there are prominent longitudinal ridges on the ventro-lateral and dorso-lateral sides of its conch, and these, together with its sinuous sutures and concave venter, differentiate it from the genotype of *Knightoceras*. In *Planetoceras* the sutures form lateral lobes rather than saddles and the conch is evolute, and in *Temnocheilus* the conch bears prominent ventro-lateral nodes.

KNIGHTOCERAS MISSOURIENSE Miller and Owen, n. sp.

Plate XV, figures 6-8

Conch moderately small, subglobular, nautiliconic, and rapidly expanded orad. Whorls strongly depressed dorso-ventrally, almost twice as wide as high, and sublenticular in cross section; they are very broadly rounded ventrally and dorsally and are subangular laterally—the dorsal impressed zone is very shallow and not very wide and it is therefore rather inconspicuous. The dorsal side of

[25] Marie Tzwetaev: Cephalopodes de la section supérieure du calcaire carbonifère de la Russie centrale. Mém. du Comité Géol., vol. 5, no. 3, 1888, pp. 15, 50.

the conch is more highly arched than is the ventral. The holotype and only known representative of this species is a well-preserved specimen representing most of the living chamber and a small portion of the penultimate volution of the conch, which is septate. This specimen is not complete orad and it is bounded apicad by an impression of the adoral septum of the phragmacone; the ventral portions of two camerae of the penultimate volution of the conch adhere to the dorsal side (impressed zone) of the living chamber. The holotype is about 34 mm. long but it apparently represents only about one-fourth of a volution of the conch; at its adapical end it is about 20 mm. wide and 11 mm. high whereas at its adoral end it is about 27 mm. wide. At the adapical end of the holotype the dorsal impressed zone is about 3 mm. wide and is less than ½ mm. deep, but near the mid-length of this specimen it is about 5½ mm. wide and 1 mm. deep.

Aperture not preserved but growth-lines indicate that it was marked ventrally by a broad deep rounded hyponomic sinus which was more or less depressed-U-shaped but had curved sides—near the mid-length of the holotype the sinus formed by the numerous fine growth-lines as they cross the broad ventral side of the conch is about 7 mm. deep. On the broad dorso-lateral sides of the conch (the umbilical walls) the growth-lines are nearly straight. The test is rather thick (averaging almost ½ mm. on the ventral side of the holotype), and along the narrow subangular lateral zones of the conch its thickness is more than trebled and a low and blunt but rather prominent keel or carina is thereby formed. Since this keel results from a thickening of the test no trace of it is discernible on the internal mold. The surface of the internal mold is smooth with the exception of a very small but distinct ridge along the venter.

On the penultimate volution of the holotype the camerae apparently are about one-third as long as wide. Each suture forms a very broad shallow broadly rounded ventral lobe and on either side of it a shallow subangular lateral saddle which centers on the subangular lateral zone of the conch; on the broad dorso-lateral sides of the conch (the umbilical walls) the sutures are nearly straight, but each forms a rather prominent rounded lobe as it crosses the dorsal impressed zone.

The siphuncle is small, is located distinctly nearer the venter than the dorsum, and is orthochoanitic in structure. At the

adapical end of the holotype the siphuncle is slightly more than 1 mm. in diameter and its center is about 4 mm. from the venter. The septal necks are straight but their length can not be determined from the holotype.

Remarks.—Only one species, *K. subcariniferum* (Tzwetaev) of the Lower Pennsylvanian of central Russia, is known that is congeneric with this form; it is much larger and its sutures are different particularly in that they form distinct lobes on the dorsolateral zones (umbilical walls) of the conch. *Planetoceras bellilineatum* Miller, Dunbar, and Condra of the Kendrick shale (upper Pottsville) of Kentucky is somewhat similar but its sinuous sutures as well as the form of its conch indicate clearly that the resemblance is superficial and that it is not closely related to the form under consideration.

Occurrence.—Immediately above the Tebo coal member of the Cherokee formation in the Edwards strip pit (sec. 23, T. 42 N., R. 26 W.), Henry County, Missouri.

Repository.—Private collection of John Britts Owen, Clinton, Missouri, No. 562.

Genus TEMNOCHEILUS M'Coy 1844

The genera *Temnocheilus, Metacoceras,* and *Domatoceras* are very closely related and it is becoming increasingly difficult to distinguish clearly between them as more and more non-typical, more or less intermediate forms are being discovered. The characteristics of each of these genera must, of course, be determined largely from its genotype. The genotype of *Temnocheilus* is *Nautilus coronatus* M'Coy of the Lower Carboniferous of Ireland and England; the genotype of *Metacoceras* is *Nautilus sangamonensis* Meek and Worthen of the Pennsylvanian (McLeansboro formation) of Illinois; and the genotype of *Domatoceras* is *D. umbilicatum* Hyatt of the Pennsylvanian (upper Cherokee) of Kansas. In so far as we have been able to ascertain from a study of the published illustrations and descriptions of these genotypes and closely related forms, the conchs of all of them are similarly coiled and are marked externally by a row of prominent ventro-lateral nodes, and there is no material difference in their sutures or their siphuncles. However, they do differ materially in cross section (see text figure 2); in *Temnocheilus*

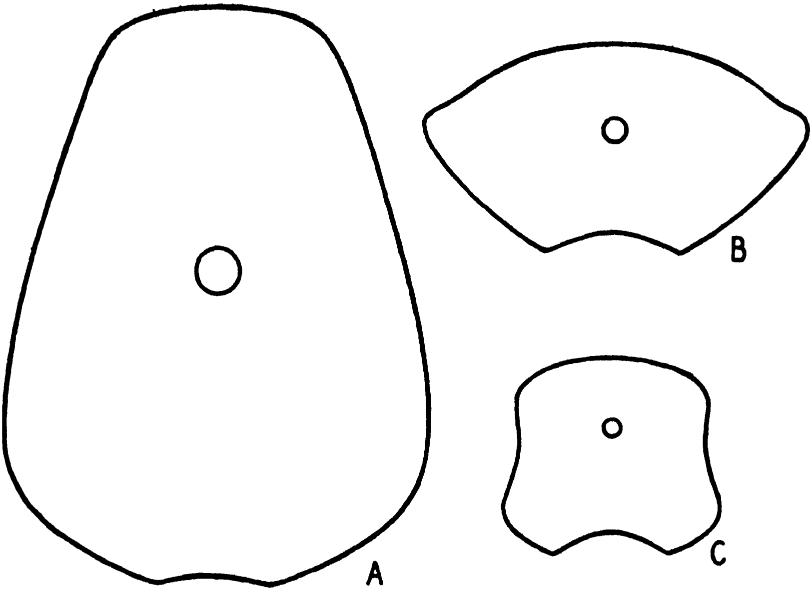

Figure 2

Figure 2.—Diagrammatic cross sections of the conchs of typical representatives of *Domatoceras, Temnocheilus,* and *Metacoceras,* based on

A—the holotype of *Domatoceras umbilicatum* Hyatt, the genotype of *Domatoceras,* x 1 (after Hyatt);

B—a typical representative of *Temnocheilus,* an unnamed species, from the Mingus shale (Strawn), near Millsap, Texas, x 1—this specimen is in the Yale Peabody Museum—; and

C—a topotype of *Metacoceras sangamonense* (Meek and Worthen), the genotype of *Metacoceras,* x 2.

the conch is strongly depressed dorso-ventrally and its lateral sides converge dorsally; in *Domatoceras* the conch is compressed laterally and its lateral sides converge ventrally; in *Metacoceras* the cross section of the conch is more or less intermediate in shape between that of *Temnocheilus* and *Domatoceras.* Furthermore, in *Temnocheilus* the ventro-lateral nodes are typically confluent whereas those of *Metacoceras* and *Domatoceras* are not, and in *Domatoceras* the ventro-lateral nodes represent merely thickenings of the test and therefore not more than a faint trace of them is retained on the internal mold whereas in both *Metacoceras* and *Temnocheilus* subdued replicas of the ventro-lateral nodes are present on the internal mold.

TEMNOCHEILUS HARNERI Miller and Owen, n. sp.

Plate XIII, figure 1; Plate XIV, figure 1

We are basing this species on two large specimens which are rather fragmentary but which supplement each other exceptionally well—one of them represents the lateral portion of the conch whereas the other represents the ventral portion. Both specimens retain the test, or rather a replacement of it, and therefore the nature of the sutures can not be ascertained.

Conch large, nautiliconic, fairly rapidly expanded orad, and subglobular in shape. Whorls are depressed dorso-ventrally, very broadly rounded ventrally, rather narrowly rounded ventro-laterally, very broadly rounded laterally, and slightly impressed dorsally; the lateral sides of the conch converge dorsally and the dorsal side is therefore very much narrower than the ventral side. The holotype (plate XIII, figure 1) shows that the conch consists of at least three volutions and attains a maximum diameter (measured from the adoral end of the venter across the umbilicus to the opposite side of the specimen) of at least 135 mm., and the paratype (plate XIV figure 1) shows that it attained a maximum width of at least 90 mm.

The narrowly rounded ventro-lateral zone of the conch bears a single row of very prominent narrowly rounded nodes which are nearly circular in cross section but are slightly elongate in a direction parallel to the long axis of the conch. On the adoral portions of the type specimens these nodes are about 10 mm. high and about 15 mm. in diameter; there are about thirteen of them to the volution. These nodes are not confluent as are those of most of the known representatives of this genus, and they project ventro-laterally rather than laterally as do those of the genotype. The extreme adapical portion of the holotype, which is not well preserved, apapparently is non-nodose, but it bears prominent longitudinal lirae on its lateral sides.

The growth-lines are numerous and very fine; they appear to be nearly straight on the lateral zones of the conch but on the broad ventral side they curve first gradually and then abruptly apicad and form a broad deep broadly rounded almost U-shaped sinus as they cross the venter; presumably these growth-lines indicate the shape of the aperture. The median third of the ventral side of the conch is essentially flat, or very slightly concave, and the borders

of this flattened zone are sharp and are rather prominent; on the adoral portion of the paratype this zone is about 30 mm. wide.

Unfortunately no information in regard to the internal structures of the conch can be gleaned from the type material.

Remarks.—This form is not closely similar to the genotype of *Temnocheilus, T. coronatus* (M'Coy) of the Lower Carboniferous of Ireland and England, but it appears to be very closely related to *T. winslowi* Meek and Worthen and *T. latus* M. and W. of the Lower Pennsylvanian of Illinois and *T. johnsoni* Miller, Dunbar, and Condra of the Lower Pennsylvanian of Colorado. In *T. latus* and *T. winslowi* the ventro-lateral nodes are more or less confluent and in *T. johnsoni* they are distinctly elongate in a direction parallel to the long axis of the conch. *T. subrectangularis* M., D., and C. of the Lower Pennsylvanian of Kentucky differs in that its conch is subrectangular in cross section and its ventro-lateral nodes are confluent—the ventro-lateral nodes of *T. subrectangularis* resemble those of the genotype, *T. coronatus,* more closely than do those of any of the species mentioned above, but the conchs of these two forms apparently are quite different in cross section.

The John Britts Owen Collection contains a small specimen (No. 559) which may represent this species but which is so incomplete that its affinities can not be determined with certainty and a satisfactory illustration of it can not be secured. This specimen is about 17 mm. long but it is not complete adorally or adapically and it apparently represents only about one-third of a volution of a coiled conch. It is depressed dorso-ventrally and its lateral sides converge dorsally as do those of *T. harneri,* but except on its adoral portion its lateral and ventral sides bear prominent longitudinal lirae but no ventro-lateral nodes are present. However, on the adoral portion of this specimen two very prominent ventro-lateral nodes are developed and the longitudinal lirae become much less prominent—they are entirely obsolete on the adoral portion of the ventral side of the conch. Tzwetaev[26] has described a representative of the genus *Temocheilus, T. acanthicus,* from the Lower Pennsylvanian of central Russia in which the adapical portion of the conch is preserved and it is longitudinally lirate but non-nodose, and a trace of similar ornamentation is discernible on the adapical portion of the holotype of *T. harneri.* It is quite possible that the specimen

[26] Op. cit., pp. 6-7, 45-46, pl. 1, fig. 2.

under consideration represents merely the adapical portion of the conch of a representative of *T. harneri*—it is septate throughout. This specimen came from immediately above an unnamed local coal, some 15 feet below the Lexington coal, in the Fowler strip pit (sec. 10, T. 43 N., R. 28 W.), Henry County, Missouri.

The species described above is named in honor of Mr. Joe Harner of Nevada, Missouri, who collected the paratype and kindly loaned it to us for study.

Occurrence.—Both of the types of this species came from the Cherokee of Missouri. The holotype came from immediately above the Tebo coal in the Tillman strip pit (NE¼NE¼ sec. 23, T. 42 N., R. 26 W.), Henry County, Missouri. The paratype came from a reddish limestone lens immediately above the Rich Hill coal (near the middle of the Cherokee), about 1½ miles northeast of Arthur, Missouri, that is, from a strip pit located in NW¼NW¼ sec. 4, T. 37 N., R. 31 W.

Repository.—Private collection of John Britts Owen, Clinton, Missouri, No. 558 (holotype); and private collection of Joe Harner, Nevada, Missouri (paratype).

TEMNOCHEILUS sp.

1891. *Temnocheilus latus* Hyatt, Texas Geol. Survey Ann. Rep. 2, pp. 330-331. [Probably not *Nautilus* (*Temnocheilus*) *latus* Meek and Worthen 1870.]
1904. *Temnocheilus latus* Beede and Rogers, Kansas Univ. Sci. Bull., vol. 2, no. 15, pp. 461, 463.

In 1891 Hyatt referred a specimen from Oswego, Kansas, in the collections of the U. S. National Museum, to *Temnocheilus latus* Meek and Worthen, but he published only the following information in regard to it:

> "This is a much compressed and distorted fossil in shaly limestone, having a line of huge tubercles and an aspect similar to that of *Temnocheilus latus* or *Winslowi*. This in common with a number of others here described from this locality were collected and presented by Dr. W. S. Newlon."

According to Beede and Rogers, this specimen came from a strip pit one and one-half miles southeast of Oswego, Kansas, and Professor R. C. Moore[27] has recently written us that this "is doubtless

[27] Personal communication, dated February 3, 1934.

the horizon of the Lexington coal, which occurs immediately below the lower Fort Scott and we should place it in the very top of the Cherokee shale." Since the type specimen of *Temnocheilus latus* came from the stratigraphic equivalent of the basal portion of the Cherokee ("Roof of Coal No. 1")[28] at Carbon Cliff, Rock Island County, Illinois, it is doubtful if the specimen from near Oswego is conspecific with it, but we have not had an opportunity to examine either specimen. It is of course quite possible that this Cherokee specimen represents the species described above as *Temnocheilus harneri*.

Genus METACOCERAS Hyatt 1883

METACOCERAS MUTABILE Miller and Owen, n. sp.

Plate XVI, figures 1, 2

Conch at maturity consists of at least two and one-half volutions, is moderate in size, subdiscoidal in form, and tarphyceraconic in its mode of growth. Whorls are slightly depressed dorso-ventrally and all volutions except the first which is elliptical in cross section are irregularly hexagonal in cross section as the conch is flattened ventrally, laterally, dorso-laterally, and dorsally; and the ventro-lateral shoulders, the umbilical shoulders, and the junctions of the dorso-lateral and the dorsal sides of the conch are very narrowly rounded or subangular. The dorsal side of the conch is slightly concave as it is impressed by the ventral side of the preceding volution. On the adoral portion of the holotype the ventral side of the conch is very slightly concave along the median zone, and the lateral sides are slightly convex; the dorso-lateral sides (the umbilical walls), however, are neither concave nor convex and they are inclined to the lateral sides at an angle of about 75 degrees. The lateral sides of the conch converge very slightly ventrad. The maximum diameter (measured from the adoral end of the venter across the umbilicus to the opposite side of the specimen) attained by the holotype, a typical mature specimen, is about 45 mm.; the diameter at right angles to this and across the umbilicus measures about 37 mm. Near the adoral end of this specimen the conch is about 20 mm. wide and about 15 mm. high; its ventral side is about 18 mm.

[28] Savage (Jour. Geol., vol. 32, 1924, p. 580) gives the horizon of this species as the McLeansboro formation, which includes the Pennsylvanian strata of Illinois above the top of Coal No. 6; it seems likely that he was referring to *T. winslowi* and not to *T. latus*.

wide; its lateral sides are about 13 mm. wide; its dorso-lateral sides (umbilical walls) are about 6 mm. wide; and its dorsal side is about 8 mm. (calculated) wide.

The umbilicus is large (but not large for this genus), moderately deep and perforate; its width is equal to almost one-half that of the specimen and the umbilicus of the holotype attains a maximum diameter of a little more than 20 mm. Since the conch is only slightly involute essentially all of the lateral sides of the earlier volutions are exposed in the umbilicus. The umbilical perforation is oval in shape and that of the holotype is about 4½ mm. long and almost 3½ mm. wide.

The surface ornamentation of the conch varies markedly during the ontogenetic development and the specific name is given to refer to this characteristic. On the extreme adapical portion of the conch (the first half-volution) the ornamentation consists of only prominent transverse lirae which are slightly sinuous. Orad of there a row of small narrowly rounded nodes is developed on each of the ventro-lateral and the dorso-lateral shoulders of the conch. Those on the dorso-lateral shoulders (the umbilical shoulders) gradually decrease in prominence on the adoral volution of the conch and on the adoral half-volution of the holotype they are entirely obsolete. The nodes on the ventro-lateral shoulders of the conch gradually increases in prominence adorally. Greatly subdued replicas of these nodes are present on the internal mold. On the adoral portion of the holotype the umbilical shoulders are very sharp and the test is thick there; on the internal mold, however, these shoulders are rounded. The surface of the test (but not the internal mold) is marked also by rather prominent growth-lines. These form very slight salients as they cross the dorso-lateral sides of the conch (the umbilical walls); they are slightly sigmoidal as they cross the lateral sides; and they form broad deep rounded more or less U-shaped sinuses as they cross the broad ventral side of the conch. The growth-lines seem to be particularly prominent on the subangular umbilical and ventro-lateral shoulders of the conch. On the internal mold (but not the exterior of the test) there is a small rounded ridge or raised line along the venter. One of the paratypes (the one represented by figure 2 on plate XVI) retains an impression of part of the apertural margins; they are of course shaped like the growth-lines and there is a small rounded lateral crest and a deep rounded hyponomic sinus. These apertural

margins are slightly depressed indicating that the test was somewhat thickened immediately adjacent to the aperture.

About three camerae (four sutures) occur in a length (measured along the venter) equal to the height of the conch. On the mature portion of the conch the sutures form a broad shallow rounded lobe on the ventral side of the conch and a similar rounded lobe on the lateral and the dorsal sides of the conch, and these are separated by subacute saddles. The part of the suture forming the dorsal side of the lateral lobe continues to curve orad across the umbilical wall and the subacute dorso-lateral saddle centers on the umbilical seam rather than on the umbilical shoulder; there is however a decrease in the amount of the adoral curvature of the sutures on the umbilical shoulder.

The siphuncle is small, subcentral in position but distinctly nearer the ventral than the dorsal side of the conch, and presumably orthochoanitic in structure. Where the conch of one of the paratypes is about 10 mm. high and about 12½ mm. wide the siphuncle is considerably less than 1 mm. in diameter and is located about 3½ mm. from the venter.

Remarks.—This species is similar to *Metacoceras angulatum* Sayre of the Westerville limestone (Kansas City) of Missouri but in that form the nodes on the umbilical shoulders do not become obsolete on the adoral portion of the conch. In *M. biseriatum,* described below, the conch is more strongly depressed dorso-ventrally and the nodes on the umbilical shoulders do not become obsolete on the adoral portion of the conch.

The collection we are studying contains numerous small representatives of *Metacoceras* some of which probably represent this species but we have not been able to differentiate satisfactorily adolescent specimens of this species from those of other congeneric forms.

Occurence.—All of the specimens we are referring to this species came from the Cherokee of Henry County, Missouri. The holotype came from immediately above the Tebo coal member of the Cherokee in the Tillman strip pits (NE¼NE¼ sec. 23, T. 42 N., R. 26 W.); the figured paratype (plate XVI, figure 2) came from the same horizon in the West Missouri Power Company strip pits (sec. 23, T. 42 N., R. 26 W.); the paratype showing the siphuncle came from the same horizon about ¼ mile north of Montrose; other specimens

which apparently represent this species came from immediately above the Lexington coal in the George Howell strip pit (sec. 19, T. 42 N., R. 25 W.), and from immediately above an unnamed local coal 10-15 feet below the Jordan coal in the England pit (sec. 17, T. 41 N., R. 25 W.).

Repository.—Private collection of John Britts Owen, Clinton, Missouri, Nos. 583-587; the holotype is numbered 583, the figured paratype 584, the paratype showing the siphuncle 585, the specimen from the Lexington coal horizon 586, and the specimens from below the Jordan coal 587.

METACOCERAS BISERIATUM Miller and Owen, n. sp.

Plate XVI, figures 5-7

Conch moderate in size and tarphyceraconic in its mode of growth. Whorls are depressed dorso-ventrally and are irregularly hexagonal in cross section; their height is equal to about two-thirds their width. On the mature portion of the conch the ventral side, though in general slightly convex, is slightly concave along the median zone. The lateral sides are neither concave nor convex. The dorso-lateral sides are slightly convex. The dorsal side is slightly concave as it is impressed by the ventral portion of the preceding volution. The ventro-lateral shoulders of the conch are rounded, but the umbilical shoulders are subangular—on the internal mold however they are rounded. The junctions of the dorso-lateral and the dorsal sides of the conch are subangular. The lateral sides of the conch converge slightly ventrad.

The holotype is an internal mold of the living chamber to which fragments of the test adhere. Also, much of the phragmacone of this specimen is available for study but it is very fragmentary and poorly preserved. The living chamber is at least one-third of a volution in length and that of the holotype was at least 45 mm. long (measured along the venter). At the adapical end of the living chamber of the holotype, a mature specimen, the internal mold of the conch is about 18 mm. wide and 12 mm. high, the ventral side is about 16 mm. wide, the lateral sides are each about 7 mm. wide, the dorso-lateral sides are each about 5 mm. wide, the dorsal side is about 8 mm. wide, and the impressed zone is about 1 mm. deep.

Umbilicus large and apparently perforate. Nearly all of the

lateral sides of the earlier volutions of the conch are exposed in the umbilicus. Umbilical walls steep and inclined to the lateral sides of the conch at about 65 degrees.

Both the ventro-lateral shoulders and the umbilical shoulders of the conch bear a single row of rather prominent, round, fairly sharp nodes; those on the ventro-lateral shoulders are much larger than are those on the umbilical shoulders. There are about 20-25 (estimated) ventro-lateral nodes to each volution, and there appears to be an umbilical node opposite each ventro-lateral node. Subdued replicas of the ventro-lateral nodes are present on the internal mold, but not more than a trace of the umbilical nodes is discernible on the internal mold. The exterior of the test is marked also by growth-lines; these are nearly straight on the lateral sides of the conch, but immediately ventrad of the narrowly rounded ventro-lateral zones of the conch they curve strongly apicad and they form broad deep rounded sinuses as they cross the ventral side of the conch—presumably they indicate the shape of the aperture.

Camerae short. Each suture forms a broad shallow broadly rounded ventral lobe, a shallow narrowly rounded ventro-lateral saddle, a broad shallow lateral lobe which extends from the ventro-lateral shoulder of the conch to the umbilical seam, a shallow subangular dorso-lateral saddle which centers on the umbilical seam, and a deeper (but nevertheless rather shallow) rounded dorsal lobe. The part of the suture which forms the dorsal side of the lateral lobe continues to curve orad as it crosses the dorso-lateral side of the conch but there is a marked decrease in the amount of adoral curvature beyond (dorsad of) the umbilical shoulder.

Siphuncle small, central (or nearly so) in position, and orthochoanitic in structure. At the adapical end of the living chamber of the holotype the siphuncle is about 1½ mm. in diameter. The septal necks are straight but short; their length is only about one-fourth that of the cylindrical connecting rings. In the adapical volution of the holotype the siphuncle is much nearer the venter than the dorsum. Also, the extreme adapical portion of the conch (the first volution) is not impressed dorsally and is subelliptical in cross section.

Remarks.—This species is similar to *Metacoceras mutabile*, described above, of the Cherokee of Missouri and to *M. angulatum* Sayre of the Westerville limestone (Kansas City) of Missouri.

However, its conch is more strongly depressed than are the conchs of either of those species and its siphuncle is central in position. Also, on the adoral portion of the conch of mature representatives of *M. mutabile* the nodes on the umbilical shoulders become obsolete whereas those in the species under consideration do not. The collection we are studying contains numerous small representatives of *Metacoceras* some of which probably represent this species but we have not been able to differentiate satisfactorily adolescent specimens of this species from those of other congeneric forms.

Occurrence.—The holotype and the three paratypes of this species all came from the Cherokee of Missouri. The holotype came from immediately above the Lexington coal in the Old Overby strip pit (NE¼NE¼ sec. 21, T. 43 N., R. 28 W.); two of the paratypes came from immediately above the Tebo coal in the Carroll pits (sec. 9, T. 42 N., R. 25 W.); the other paratype came from immediately above the Lexington coal in the Geo. Howell pit (sec. 19, T. 42 N., R. 25 W.)

Repository.—Private collection of John Britts Owen, Clinton, Missouri, Nos. 599 (holotype) and 600, 601 (paratypes).

METACOCERAS sp.

Plate XVI, figures 8, 9

The collection we are studying contains a single large fragment (an internal mold) of a large representative of the genus *Metacoceras* that apparently is not referable to any described species but is too incomplete to serve as the type of a new species. The lateral sides of this specimen converge dorsally rather than ventrally as is typical for this genus, and the maximum width of the conch is therefore attained at the ventro-lateral shoulders. The narrowly rounded ventro-lateral zones of the specimen bear a single row of large prominent rounded nodes, but the umbilical shoulders are rounded and are non-nodose. There is a small rounded ridge or raised line along the venter. About five camerae occur in a length (measured along the venter) equal to the maximum width of the conch. Each suture forms a very broad shallow broadly rounded ventral lobe and a similar lateral lobe, and these are separated by a shallow rather narrowly rounded ventro-lateral saddle. The siphuncle is small and is central or nearly so in position; presumably it is orthochoanitic in structure.

Occurrence.—Immediately above the Tebo coal member of the Cherokee in the Carroll strip pits (sec. 9, T. 42 N., R. 25 W.), Henry County, Missouri.

Repository.—Private collection of John Britts Owen, Clinton, Missouri, No. 605.

Genus PARAMETACOCERAS Miller and Owen, n. gen.

The collection we are studying contains numerous representatives of a species which, though somewhat similar to the type of *Metacoceras,* is generically distinct from it and is not referable to any described genus; we are proposing the generic name *Parametacoceras* for this and congeneric forms. Tzwetaev[29] has described a closely related species, *Nautilus nikitini,* from the Upper Carboniferous of central Russia; Miller[30] has described a form, *Endolobus schucherti,* from the Pennsylvanian of New Mexico that probably is congeneric; Hyatt[31] has described a species, *Temnocheilus crassus,* from the Cherokee of Kansas that may represent this genus; and the John Britts Owen collection contains a specimen (number 619) from the Lower Pennsylvanian near Danville, Kentucky, that represents an undescribed species closely similar to the genotype. These forms differ from typical *Metacoceras* particularly in that the ventro-lateral shoulders of their conchs do not bear a row of prominent nodes and their lateral sides are ornamented by transverse ribs. The new genus can be briefly characterized as follows:

Conch tarphyceraconic and typically slightly evolute. Whorls subquadrate in cross section. Umbilicus large and perforate. Aperture marked ventrally by a broad deep rounded hyponomic sinus. On mature portion of conch lateral sides of whorls bear short transverse ribs. Each suture forms very shallow broadly rounded ventral, lateral, and dorsal lobes and these are separated by similar but more narrowly rounded ventro-lateral and dorso-lateral saddles. Siphuncle small, subcentral or subventral in position, and orthochoanitic in structure. Genotype *Parametacoceras bellatulum* Miller and Owen, described below.

As indicated by the generic name this genus is closely related to

[29] Op. Cit., 10-11, 47-48, pl. 1, figs. 5.

[30] A. K. Miller: A Pennsylvanian cephalopod fauna from south-central New Mexico. Jour. Paleontology, vol. 6, 1932, pp. 64-66, pl. 12, figs. 12, 13.

[31] Alpheus Hyatt: Carboniferous cephalopods. Texas Geol. Survey, Ann. Rep. 2, 1891, p. 333, text figs. 27-29.

Metacoceras and occurs in association with it; it should be placed in the *Tainoceratidae* next to *Metacoceras*. It differs from *Endolobus* and *Diodoceras* in that its conch is not strongly depressed dorso-ventrally and is subquadrate rather than subelliptical in cross section. It lacks the prominent ventro-lateral nodes which are so characteristic of *Metacoceras, Temnocheilus,* and *Tainoceras.*

PARAMETACOCERAS BELLATULUM Miller and Owen, n. sp.

Plate XV, figures 1-5

Conch moderately small and tarphyceraconic, and at maturity consists of about two and one-fourth volutions. First volution of conch is subelliptical in cross section—its dorsal side is more strongly arched than its ventral—but orad of there the conch is impressed dorsally and its ventral, lateral, and dorso-lateral sides are gradually flattened so that the adoral portion of the second volution is irregularly hexagonal in cross section—the ventro-lateral zones of the conch are narrowly rounded; the umbilical shoulders and the junctions of the dorsal and dorso-lateral sides are subangular. Orad of the second volution the conch gradually becomes less strongly impressed dorsally and the extreme adoral portion of the conch is therefore subquadrate in cross section, or, as it is depressed dorso-ventrally, subrectangular. On the outer volution of the holotype all of the sides except the dorsal impressed zone are slightly convex but on the adoral portion of the conch the ventral side is nearly flat. The living chamber is about one-third of a volution in length.

The holotype (plate XV, figures 1-3) is a typical mature specimen; its maximum diameter, measured from the adoral end of the venter across the umbilicus to the opposite side of the specimen, is about 31 mm.; the diameter at right angles to this and across the umbilicus measures about 26 mm. At the adoral end of the holotype, which is essentially complete, the conch is about 21 mm. wide and about 14 mm. high; at the adapical end of the outer volution the conch is only about 9 mm. wide and 6 mm. high.

The umbilicus is wide and perforate. Its width is equal to about two-fifths the diameter of the specimen and that of the holotype attains a maximum diameter of about 12½ mm. The umbilical walls are steep and are inclined to the nearly flat lateral sides of the conch at some 80 degrees. The umbilical perforation is oval in shape and that of the holotype is about 3 mm. long and 2 mm. wide.

On the adoral half-volution of mature specimens the umbilical shoulders are subangular but apicad of there they are narrowly rounded, and on the internal mold they are rounded throughout their entire length.

The first half-volution of the conch is marked externally by rather prominent transverse lirae which are slightly sinuous, but orad of there these lirae disappear and small low rounded transverse ribs are developed on the lateral sides of the conch. There are about twenty-five (estimated) of these ribs to the volution. They end rather abruptly in small rounded nodes on the ventral portion of the lateral sides but on the dorsal portion of those sides these ribs die out gradually (see figure 5 on plate XV). On the adoral fourth of the outer volution of mature specimens the ribs become obsolete. Subdued replicas of these ribs are discernible on the internal mold. The exterior of the test but not the internal mold is marked also by rather prominent growth-lines. These form very slight salients as they cross the umbilical walls and are very slightly sinuous on the lateral sides of the conch, but immediately ventrad of the ventro-lateral shoulders, they curve strongly apicad and form very broad deep rounded sinuses as they cross the broad ventral side of the conch. These growth-lines of course indicate the shape of the aperture, and on some of the type specimens where portions of the apertural margins are preserved the growth-lines are parallel to them.

The camerae are moderate in length and along the venter the distance between successive sutures is equal to about one-third the width of the conch. On the adapical portion of the conch the sutures are straight but on the outer volutions each suture forms a shallow rounded lobe as it crosses the ventral side of the conch, a similar ventro-lateral saddle, a similar but broader lateral lobe, a low narrowly rounded dorso-lateral saddle which centers on the umbilical seam, and a deep rounded dorsal lobe as it crosses the impressed zone. On the adoral portion of mature specimens, where the conch is irregularly hexagonal in cross section, the part of the suture which forms the dorsal side of the lateral lobe continues to curve orad as it crosses the umbilical wall but there is a marked decrease in the amount of its adoral curvature dorsad of the umbilical shoulders. There is a small rounded pit or depression in each septum next to the dorsum. On the adoral portion of the internal

mold of some of the types there is a small rounded ridge or raised line along the venter.

The siphuncle is small in size, subcentral in position but distinctly nearer the venter than the dorsum, and orthochoanitic in structure. The septal necks are about one-third as long as the cylindrical connecting rings. In one of the figured paratypes (plate XV, figure 4), where the internal mold is about 11 mm. wide and 7½ mm. high, the siphuncle is slightly less than 1 mm. in diameter and its center is about 2½ mm. from the venter.

Remarks.—This species is more closely similar to *Parametacoceras nikitini* (Tzwetaev) of the Upper Carboniferous of central Russia than to any other described species, but it is readily differentiated from that form by the subrectangular (rather than elliptical) cross section of its conch, and by the fact that its siphuncle is nearer the venter than the dorsum (rather than central in position). In *Parametacoceras schucherti* (Miller) of the Pennsylvanian of New Mexico the cross section of the conch and the shape of the lateral ribs are different, and in *P.? crassus* (Hyatt) of the Cherokee of Kansas the conch is less rapidly expanded orad and is compressed rather than depressed.

Occurrence.—All of the specimens that we are referring to this species came from immediately above the Lexington coal member of the Cherokee in Henry and Lafayette counties, Missouri. The holotype and eleven of the paratypes came from the Ewing strip pit (sec. 36, T. 43 N., R. 28 W.), Henry County; seven of the other paratypes (including the one represented by figure 5 on plate XV) came from the Lear pit (sec 15, T. 43 N., R. 28 W.), Henry County; the other figured paratype (plate XV, figure 4), and an unfigured one, came from the SE¼NW¼ sec. 15, T. 49 N., R. 25 W., Lafayette County; another paratype came from the Old Overby strip pit (sec. 21, T. 43 N., R. 28 W.), Henry County; and the other paratype came from the Old Gooch strip pit (sec. 15, T. 43 N., R. 28 W.), Henry County.

Repository.—Private collection of John Britts Owen, Clinton, Missouri, Nos. 606 (holotype), 607 (figured paratype, figure 5 on plate XV), 608 (figured paratype, figure 4 on plate XV), and 609-612 (unfigured paratypes).

PARAMETACOCERAS? CRASSUM (Hyatt)

Text figures 3a-3c

1891. *Temnocheilus crassus* Hyatt, Texas Geol. Survey Ann. Rep. 2, p. 333, text figs. 27-29.

1893. *Temnocheilus crassus* Hay, Kansas Acad. Sci. Trans., vol. 13, pp. 38-39, text figs. 3-5.

1904. *Temnocheilus crassus* Beede and Rogers, Kansas Univ. Sci. Bull., vol. 2, no. 15, pp. 461, 463.

1933. *Metacoceras crassum* Miller, Dunbar, and Condra, Nebraska Geol. Survey Bull. 9, ser. 2, pp. 168, 195.

No representative of this unique species other than the holotype has ever been found. Since Hyatt's illustrations and description are not readily available to most paleontologists, we are reproducing them.

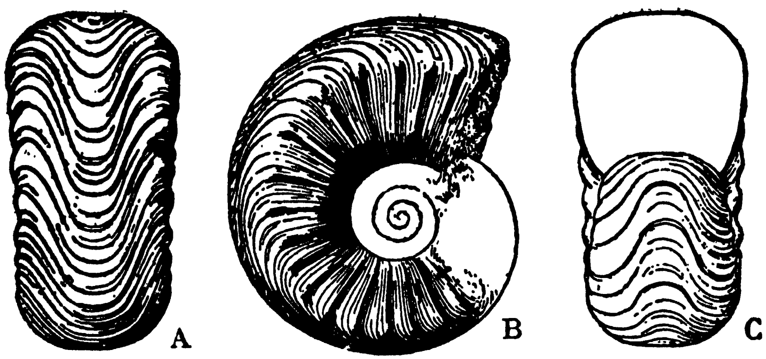

Figure 3

Figure 3.—Three views of the holotype of *Parametacoceras? crassum* (Hyatt), x 1⅛; from immediately above the Lexington coal (Cherokee), near Oswego, Kansas. Figure C is in part a restoration. After Hyatt.

"This species is represented only by a fragment, but the characteristics are so peculiar that there is apparently little doubt of its being the representative of a distinct form.

"The sides are convex and do not converge towards the umbilici so abruptly as in most forms of this genus. They are covered by numerous well defined straight pilae, terminating in small nodes at the edges of the abdomen. The abdomen is convex, with a narrow slightly depressed zone along the centre. The shell is ornamented by prominent striae of growth, and at regular intervals one of these is more prominent than the neighboring striations, showing frequent short arrests of growth. These striae are straight upon the sides,

but upon the abdomen bend suddenly posteriorly, forming wide sinuses of great depth; doubtless the aperture was similar. The sutures are almost straight on the sides and have a very broad and slight ventral lobe. Siphuncle unknown.

"This shell is very similar to *Nautilus falcatus*, L. [J.] de C. Sowerby[32], in so far as they both have ribs. The Coalbrookdale specimen, however, has no tubercles, or at least none are given, and the sides of the whorl are figured as concave. *Naut. Nikitini*, Tzwetaev[33], is also very similar, but the ribs are less numerous and the sutures quite different. *Nikitini* has saddles and lobes as in *Tainoceras*. Living chambers were not observed. Position of siphuncle is unknown."

Remarks.—We are very uncertain in regard to the generic affinities of this form. The lateral ornamentation of its conch is strikingly similar to that of *Parametacoceras bellatulum*, the genotype of *Parametacoceras*, but the shape of its conch and the nature of its umbilicus are quite different from those of that form. Nevertheless, this species appears to be more closely related to *Parametacoceras bellatulum* than to any other genotype, and we are accordingly placing it with question in *Parametacoceras*. It is so distinct from all described species that specific comparisons would be superfluous.

Occurrence.—Hyatt states only that the holotype came from the Carboniferous near Oswego, Kansas. However, Beede and Rogers state that it came from a strip pit one and one-half miles southeast of Oswego, and Professor R. C. Moore[34] has recently written us that "this is doubtless the horizon of the Lexington coal, which occurs immediately below the lower Fort Scott and we should place it in the very top of the Cherokee shale."

Repository.—According to Hyatt the holotype is in the U. S. National Museum.

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[32] Joseph Prestwich, Jun.: On the geology of Coalbrook Dale. Geol. Soc. London Trans., ser. 2, vol. 5, 1840, pl. 40, fig. 9.

[33] Op. cit., pl. 1, fig. 5.

[34] Personal communication, dated February 3, 1934.

Genus ENDOLOBUS Meek and Worthen, 1865

ENDOLOBUS DEPRESSUS (Hyatt)

Text figures 4a, 4b

1891. *Temnocheilus depressus* Hyatt, Texas Geol. Survey Ann. Rep. 2, pp. 331-332, text figs. 25, 26.
1904. *Temnocheilus depressus* Beede and Rogers, Kansas Univ. Sci. Bull., vol. 2, no. 15, pp. 461-463.
1933. *Endolobus depressus* Miller, Dunbar, and Condra, Nebraska Geol. Survey Bull. 9, ser. 2, p. 194.

Only one representative of this species, the holotype, has been found. It was described by Hyatt as follows:

"The young of this fossil was not visible, the whole umbilical area being concealed on both sides by matrix. The sides are very narrow, convex, and very abruptly convergent to the umbilici. Their junctions with the abdomen are subangular, with a row of obscure elongated nodes, which are more marked on the shell than on the cast, and better marked on one side than on the other. The shell has fine striae of growth almost straight or only slightly concave on the sides and bending backwards on the abdomen to form broad and apparently deep sinuses. These sinuses are, however, much broader in proportion and not as deep apparently as those in the striae on the abdomen of *Tem. crassus*.

"The sutures are only slightly concave on the sides and have very broad and extremely slight lobes on the abdomen. They are numerous, and the interspaces of the air chambers quite narrow. The tubercles are more obscure than in other species on the cast and also less prominent on the shell; the air chambers are also narrower than usual in species of similar proportions. It is similar to *T. conchiferus* in the slight character of the nodes and transverse section of whorl, but the increase by growth is less, in *T. conchiferus* the nodes extend internally across the longitudinal axis of the whorl, whereas in this species they extend parallel with that axis, and the shell is thicker in *conchiferus*.

"It is closely similar to *Temnocheilus coronatus* as figured by De Koninck[35] in his Calcaire Carbonifere; but our species has an abdomen somewhat more depressed and very much broader in proportion to the abdominal and dorsal diameter at the same age, and

[35] L.-G. de Koninck: Faune du calcaire carbonifère de la Belgique; première partie, poissons et genre nautile. Musée Royal d'Histoire Naturelle de Belgique, tome 2, 1878, pl. 24, fig. 2.

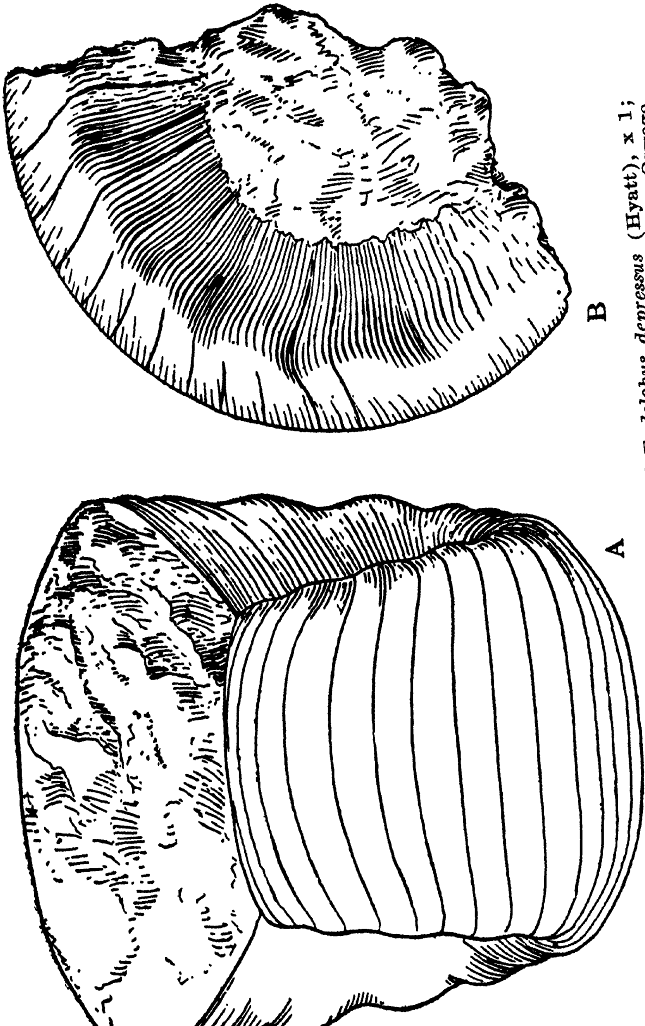

Figure 4.—Two views of the holotype of *Endolobus depressus* (Hyatt), x 1; from immediately above the Lexington coal (Cherokee), near Oswego, Kansas. Figure A is in part a restoration. After Hyatt.

the nodes are less prominent. It is similar to *Tem. latus* and *Winslowi* in the transverse section of the whorls and umbilici, but the nodes are more numerous and much smaller. It differs from *Tem. Forbesianus* in having a much broader whorl at the same age and much deeper and more funnel-like umbilici, the nodes are not so heavy and are closer together, but the sutures are similar in both. No living chamber was observed. Position of siphuncle is unknown.''

Remarks.—In general shape and ornamentation of conch this species resembles rather closely the genotype of *Endolobus, E. spectabilis* (Meek and Worthen) [= *Nautilus* (*Endolobus*) *peramplus* M. and W.] of the Chester of Illinois, but it differs from that species particularly in that its sutures form very shallow ventral lobes rather than saddles—also its conch is considerably broader. These differences do not seem to us to be sufficient to differentiate these two forms generically and we are accordingly referring this species to the genus *Endolobus*. The nodes on this form are lateral in position, rather than ventro-lateral as they are in *Temnocheilus*.

Occurrence.—Hyatt states only that the holotype came from the Carboniferous, near Oswego, Kansas. However, Beede and Rogers state that it came from a strip pit one and one-half miles southeast of Oswego, and Professor R. C. Moore[36] has recently written us that ''this is doubtless the horizon of the Lexington coal, which occurs immediately below the lower Fort Scott and we should place it in the very top of the Cherokee shale.''

Repository.—According to Hyatt the holotype is in the U. S. National Museum.

ENDOLOBUS sp.

The collection we are studying contains portions of two whorls of a large specimen (at least 125 mm. in diameter) which represents the genus *Endolobus* and which appears to be specifically distinct from all described forms. Unfortunately this specimen is so incomplete and poorly preserved that a satisfactory illustration of it can not be obtained and it should not be made the type of a species. In general form and ornamentation this specimen resembles *Endolobus depressus* (Hyatt), described above, but its conch is consider-

[36] Personal communication, dated February 3, 1934.

ably narrower and the nodes on the lateral sides of it are much less prominent. The sutures are nearly straight (very slightly convex apicad) on the umbilical walls, but immediately ventrad of the narrowly rounded lateral zones of the conch the sutures curve distinctly apicad and apparently each forms a broad shallow ventral lobe. The siphuncle is small, subcentral in position, and orthochoanitic in structure. The septal necks are straight and they are about one-third as long as the connecting rings. At least the internal mold of the penultimate volution of this specimen is nonnodose, and it resembles somewhat the figured type of *Nautilus* [*Endolobus?*] *atuberculatus* Tzwetaev[37] of the Upper Carboniferous (Dewiatowo oölite) of central Russia, but in that form the siphuncle is subventral in position and the sutures form definite lobes on the umbilical walls.

Occurrence.—Imediately above the Tebo coal member of the Cherokee formation in the Bradley strip pits (sec. 17, T. 43 N., R. 24 W.), Henry County, Missouri.

Repository.—Private collection of John Britts Owen, Clinton, Missouri, No. 616.

Genus Domatoceras Hyatt 1891

Recently Miller, Dunbar, and Condra[38] proposed the generic term *Pseudometacoceras* [genotype, *Metacoceras sculptile* Girty] for forms which they recognized are closely related to *Domatoceras* but which they believed differed from the type of that genus in that at maturity they develop a row of nodes on each of the ventrolateral shoulders of the conch and therefore mimicked *Metacoceras* in surficial features. The collection we are studying contains a number of internal molds which are so similar to the genotype of *Domatoceras* (*D. umbilicatum* Hyatt, known only from internal molds) that at first we believed them to be conspecific with it—certainly they are congeneric. Some of our specimens retain portions of the test and it (but not the internal mold) bears ventrolateral nodes on its mature portions. After carefully comparing these specimens with the published illustrations and description of the cotypes of "*Metacoceras*" *sculptile* we have concluded that our specimens may not differ specifically from them. Since the geno-

[37] Op. cit., pl. 1, fig. 6.
[38] Op. cit., p. 224.

types of *Pseudometacoceras* and *Domatoceras* are so similar that it is not easy to differentiate them specifically they should not be differentiated generically and the generic name *Pseudometacoceras* is therefore to be suppressed as a synonym of *Domatoceras*. The close relationship between the genotypes of *Domatoceras* and *Pseudometacoceras* was not suspected heretofore as one of them is based on specimens retaining the test whereas the other is based on internal molds.

DOMATOCERAS UMBILICATUM Hyatt

Text Figures 2A, 5A, 5B

1891. *Domatoceras umbilicatum* Hyatt, Texas Geol. Survey Ann. Rep. 2, pp. 343-345, text figs. 45-47.
1891. *Koninckioceras umbilicatum* Hyatt, Texas Geol. Survey Ann. Rep. 2, p. 344.
1893. *Domatoceras umbilicatum* Hay, Kansas Acad. Sci. Trans., vol. 13, pp. 42-43, text fig. 12.
1893. *Domatoceras umbilicatum* Hyatt, Texas Geol. Survey Ann. Rep. 4, p. 441.
1904. *Domatoceras umbilicatus* Beede and Rogers, Kansas Univ. Sci. Bull., vol. 2, no. 15, pp. 461, 463.
1933. *Domatoceras umbilicatum* Miller, Dunbar, and Condra, Nebraska Geol. Survey Bull. 9, ser. 2, pp. 217-218.

This species is more than ordinarily important for it is the genotype of *Domatoceras*. It was originally described by Hyatt as follows:

"This species reaches a considerable size, the specimen here described being about 217 mm. in diameter.

"The living chamber is incomplete, and is a trifle over one-fourth of a volution in length. The narrowing of the abdomen with increase of age is very marked on the living chamber in this specimen. It measures 192 mm. in length along the abdomen, 73 mm. in the abdomino-dorsal diameter at the last septum, and about 52 mm. in the transverse diameter at the umbilical shoulders, and 34 mm. near the venter. The sides of the whorls are flattened and converge outwardly, so that the abdomen is considerably less in breadth than the dorsum in the large full grown stage. There is a shallow impressed zone upon the dorsum, which occupies about one-third of its width and is due to the slight rotundity of the abdomen and the small amount of involution in the coiling of the whorls. The umbilical shoulders stand out abrupt and broad, giv-

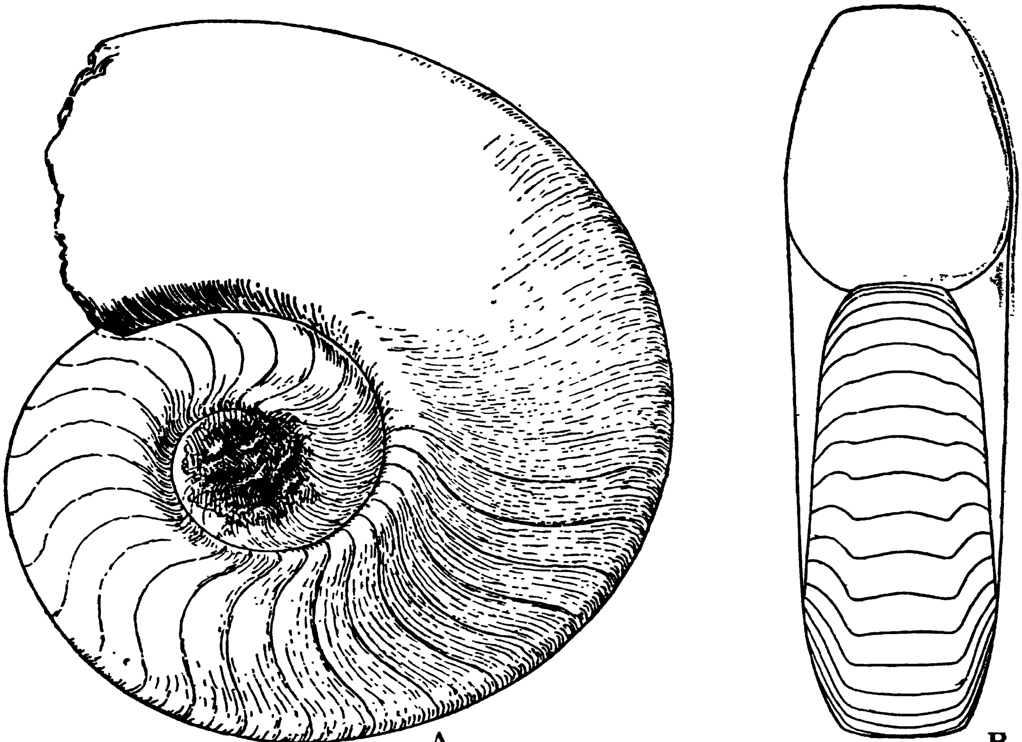

Figure 5.—Two views of the holotype of *Domatoceras umbilicatum* (Hyatt), x ½; from immediately above the Lexington coal (Cherokee), near Oswego, Kansas. Figure B is in part a restoration. After Hyatt. (See also text figure 2A.)

ing a depth to the wide umbilicus which is a marked characteristic. The sutures have shallow ventral [and] lateral lobes. The saddles at the umbilical shoulders are broad and extend inwards to the edges of the impressed zone, and then the sutures bend toward the apex, forming a shallow dorsal lobe. There are no annular lobes in the centre of the dorsal sutures. The siphon is above the centre and is apparently nummuloidal. At the diameter of 95 mm. the whorl has the following measurements: Abdomino-dorsal diameter, 41 mm.; transverse through the umbilical shoulders, 32 mm.; and breadth of the abdomen was 25 mm.

"*Domatoceras* (*Nautilus*) *complanatum*, sp. Sow. Min. Conc., Pl. 261, from Isle of Man, from Carboniferous, is another form of this genus having a very slight involution, with a compressed whorl and sub-acute abdomen. The involution is very slight in this species, exposing all the internal whorls, but in the transverse section of the outer whorl and in the sutures it is unquestionably related to the species described above. The living chamber is over one-half of a volution in length, but it is not certain from the drawing that it is completed.

"The species differs from (*Discites*) *Highlandense*, Meek and Worthen,[39] in being much larger, in having stouter whorls. The sutures are, however, evidently very similar. *Highlandense* is described as having a narrow periphery, whereas this shell when about the same size as the specimen figured in the Illinois survey has an abdomen almost as broad as the dorsum and very much broader proportionately than in its own adult whorl. It differs from (*Naut.*) *planovolve*, Shumard[40], in size and in having whorls with more rapid growth, and probably a wider and deeper umbilicus than in that species.

"It differs from the nearest European congener, *Kon. infundibulum*, as figured by De Koninck[41], in having a narrower abdomen and a more compressed form of whorl in the adolescent and adult stages; also in the sutures, which have a more marked abdominal lobe. It differs from *Kon.* (*Nautilus*) *podolskense*, Marie Tzwetaev[42],

[39] F. B. Meek and A. H. Worthen: Descriptions of invertebrates. Illinois Geol. Survey, vol. 6, 1875, p. 531, pl. 33, fig. 2.

[40] B. F. Shumard and G. C. Swallow: Descriptions of new fossils from the Coal Measures of Missouri and Kansas. St. Louis Acad. Sci. Trans., vol. 1, 1858, p. 198.

[41] Op. cit., 1878, pl. 24, figs. 1a, 1b.

[42] Op. cit., pl. 3.

in the young. This is similar to the adult in the proportions of the parts, but in *K. podolskense* the young whorl has an abdomen broader than the dorsum. The adult of this species also has a broader abdomen than the adult of our shell. The species evidently stands just between the genus represented by such species as *Kon. ingens, implicatum,* described by De Koninck, and *K. podolskense,* all of which have stout whorls with broad abdomens, and whorls similar to those of the young of *K. umbilicatum,* and those species of the same genus having more contracted abdomens, like *mosquensis* (sp. Tzwetaev), *planotergatum* as figured by De Koninck, and *Highlandense* (sp. M. and W.).

"The last whorl was considerably altered by compression on one side, and the drawings of the section and front view (Figs. 2A, 5B) are in a measure restorations."

Remarks.—In 1893 Hyatt pointed out that the next-to-the-last paragraph of this description "has unfortunately brought an element of confusion into the forms attributed to this genus [*Domatoceras*], owing to errors in the manuscript caused by the introduction of the new generic name, Domatoceras, after the text had been written. Thus *D. umbilicatum* is there referred to as *Kon. umbilicatum.*" He then referred *Nautilus podolskensis, N. inostranzwei, N. mosquensis,* and *N. lasallenis* to *Domatoceras* and stated that *N.* (*Discites*) *highlandensis, Domatoceras simplex,* and *D. militarium* may be congeneric; he referred *N. ingens, N. implicatus, N. subcariniferus,* and *Temnocheilus scottensis* to *Koninckioceras* and *N. infundibulus* and *N. planotergatus* to *Coelonautilus*; and he stated that *N. complanatus* could not be referred safely to any genus as Sowerby's figure of the type specimen of that species is inaccurate.

In 1933 Miller, Dunbar, and Condra[43] studied a representative of this species "in the collections of the Geological Survey of Kansas, which has been sectioned to show the siphuncle in the last volution. This specimen shows that the siphuncle is smaller than Hyatt inferred and that it is definitely orthochoanitic, the septal necks being rather short and straight. It has a diameter of only 2.5 mm. where the whorl has a height of 45 mm. Its position is a little below the center of the whorl, the distance from its center to the dorsum being 26 mm. and to the venter 18 mm."

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[43] This specimen was studied by C. O. Dunbar and neither of the authors of the present report has seen it.

Occurrence.—Hyatt states only that the holotype came from Oswego, Kansas. However, Beede and Rogers state that it came from a strip pit one and one-half miles southeast of Oswego, and Professor R. C. Moore[44] has recently written us that "this is doubtless the horizon of the Lexington coal, which occurs immediately below the lower Fort Scott and we should place it in the very top of the Cherokee shale." Miller, Dunbar, and Condra did not state where the specimen referred to by them was collected.

Repository.—According to Hyatt the holotype is in the U. S. National Museum, and the specimen discussed by Miller, Dunbar, and Condra is stated by them to be in the collections of the Kansas Geological Survey.

DOMATOCERAS WILLIAMSI Miller and Owen, n. sp.

Plate XVI, figure 4; Plate XVII, figures 1-4; Plate XVIII, figure 1

Conch, which at maturity consists of about three and one-half volutions, is large, tarphyceraconic in its mode of growth, gradually expanded orad, and subdiscoidal in shape. On the mature portion of the conch the whorls are compressed laterally and are irregularly hexagonal in cross section. The ventral and lateral sides are essentially straight, the dorso-lateral sides are slightly convex, and the dorsal side is slightly concave. The ventro-lateral shoulders of the conch are so abrupt as to appear subangular; the dorso-lateral shoulders also are abrupt but they are rounded; and the junctions of the dorso-lateral and dorsal sides are angular. The lateral sides are much larger than are the dorso-lateral and they converge ventrad; the dorso-lateral sides converge dorsad; and the maximum width of the conch is therefore attained at the junctions of the lateral and the dorso-lateral sides, that is, at the umbilical shoulders. The ventral side is wider than the dorsal.

The largest representative of this species that we have seen attains a maximum diameter, measured from the adoral end of the venter across the umbilicus to the opposite side of the specimen, of at least 150 mm., and it is not complete orad. The large figured specimen (plate XVIII, figure 1), an internal mold, attains a maximum diameter of about 130 mm., a maximum height of conch of about 43 mm., and a maximum width of conch of about 36 mm.; near the adoral end of this specimen the ventral side of the conch

[44] Personal communication, dated February 3, 1934.

is about 20 mm. wide, the lateral sides about 30 mm. wide, the dorso-lateral sides about 15 mm. wide, and the dorsal side about 16 mm. wide. The impressed zone is very shallow and where the conch is about 25 mm. high the impressed zone is only about 1½ mm. deep.

Due to the rather loose coiling of the conch the umbilicus is wide and it is perforate. The umbilical perforation is oval in shape and that of one of the figured specimens (plate XVII, figure 2) is about 6¼ mm. long and 4 mm. wide. The diameter of the umbilicus is equal to slightly more than half the diameter of the specimen, and the maximum diameter attained by the umbilicus of the large figured specimen (plate XVIII, figure 1) measures about 70 mm. The umbilical shoulders though abrupt are rounded, and the umbilical walls are stepped but are not very steep.

None of the specimens available for study retains the apertural margins, but the growth-lines indicate that the aperture was marked ventrally by a broad deep depressed-U-shaped hyponomic sinus.

The extreme adapical portion of the conch is subcircular in cross section—there is of course no impressed zone on the first volution. At the adoral end of the first volution the lateral and ventral (but not the dorsal) sides of the conch are greatly flattened but the lateral sides do not converge ventrally and the conch is distinctly depressed dorso-ventrally. At the adoral end of the second volution the maximum width and height of the conch are approximately equal and the lateral sides of the conch converge ventrad slightly; orad of there the conch becomes progressively more strongly compressed laterally and as the lateral sides converge ventrally more and more strongly the ventral side becomes relatively narrow.

The surface of the test is marked by numerous fine growth-lines. On the dorso-lateral sides of the conch these are nearly straight. On the lateral sides they are sigmoidal as they form broad shallow sinuses on the dorsal half of these sides and similar salients on the ventral half. On the ventral side of the conch the growth-lines form deep rounded depressed-U-shaped sinuses. On the inner volutions of the conch there is a rather narrow shallow groove with definite borders just inside (ventrad of) each ventro-lateral shoulder of the conch but these grooves apparently do not exist on the outer volution. The growth-lines are continuous across these grooves and they appear to be more than ordinarily prominent as they cross the narrow subangular ventro-lateral shoulders of the conch. On the

outer volution of large mature specimens a row of blunt narrowly rounded rather prominent nodes is gradually developed on each of the ventro-lateral shoulders—these nodes first become discernible when the conch has attained a diameter of some 55 or 60 mm. and they rapidly increase in prominence adorally; they are longitudinally elongate and are more or less confluent. On the adoral portion of the outer volution of large mature specimens a row of low and rounded but rather prominent transversely elongate nodes or short ribs is developed on each of the dorso-lateral shoulders; these do not extend far dorsad but they extend at least halfway across the lateral sides; they first become discernible when the conch has attained a maximum diameter of some 65 or 70 mm. and they rapidly increase in prominence adorally. There does not appear to be any relation between the spacing of these nodes and those developed on the ventro-lateral shoulders but this needs verification. Both the ventro-lateral and the dorso-lateral nodes are formed by a thickening of the test and therefore not more than a trace of them is discernible on the internal mold. The internal mold is essentially smooth with the exception of a small rounded inconspicuous ridge or raised line along the venter.

The camerae are rather short and about four or four and one-half of them occur in a length equal to the height of the conch. On the extreme adapical portion of the conch the sutures are straight and form simple circles but orad of there they gradually become slightly sinuous, and on the mature portion of the conch each suture forms a broad shallow broadly rounded ventral lobe and on either side of it a subangular saddle which centers on the ventro-lateral shoulder of the conch, a very broad relatively shallow broadly rounded lateral lobe, and a low broad subangular dorso-lateral saddle which centers on the umbilical seam and extends to the broad shallow broadly rounded dorsal lobe on the impressed zone; each suture form a single broad lobe as it crosses the lateral and dorso-lateral sides of the conch but there is a marked decrease in

Figure 6.—Diagrammatic representation of a mature suture of *Domatoceras williamsi*, n. sp., x 1; based on a specimen from immediately above the Tebo coal (Cherokee), in Henry County, Missouri—this is the same specimen that is represented by figures 2-4 on plate XVII.

the amount of its adoral curvature as it crosses the umbilical shoulder and continues to the umbilical seam.

Siphuncle small, circular in cross section, located distinctly nearer the venter than the dorsum, and orthochoanitic in structure; the septal necks are short and straight—their length is equal to about one-eighth the length of the camerae—and the connecting rings are not expanded within the camerae so the segments of the siphuncle are cylindrical in shape (see plate XVI, figure 4). In one of the figured specimens (plate XVII, figure 4), where the conch is about 26 mm. high the siphuncle is slightly less than 2 mm. in diameter and is located about 10 mm. from the venter.

Remarks.—We have more than twenty representatives of this species, all of which came from the Cherokee of Missouri. The specific name is given in honor of Dr. James S. Williams of the U. S. Geological Survey.

It is quite possible that the type specimens of this species are conspecific with those of *Domatoceras umbilicatum* Hyatt of the Cherokee of Kansas, *D. mosquense* (Tzwetaev) of the Upper Carboniferous (Dewiatowo oölite) of central Russia, or *D. sculptile* (Girty) of the Wewoka formation (Marmaton) of Oklahoma. Unfortunately the precise relationship between the types of these four species can not be determined from the available material. Only internal molds of *D. umbilicatum* are known, and the only published illustrations of that species are not entirely satisfactory as they are in part restorations; if they are accurate, the conch of that species is relatively higher than that of the other three species under consideration—also the holotype of that species is much larger than any known representative of the other three species. The mature portions of the conch of *D. mosquense* are known from only the internal mold and therefore adequate comparisons are not possible; the internal mold of that form is very similar to that of *D. williamsi* but the exterior of the test may well be quite different. *D. sculptile* is known from only relatively small testaceous specimens, and whereas these are strikingly similar to equisized specimens of *D. williamsi*, there is no good reason to assume that the Wewoka form attains as large a size as does *D. williamsi* and that its adoral portions are precisely similar to those of *D. williamsi*. Any or all of these four forms may prove to be conspecific. *D. highlandense* (Worthen) of the McLeansboro of Illinois is also very similar to *D. williamsi* but it is so poorly known that adequate comparisons

are not possible; nevertheless, at least on the lateral sides of its conch the sutures of *D. highlandense* are less strongly curved than are those of *D. williamsi,* and these two forms are almost certainly not conspecific.

Mr. Harold Stoneman of Springfield, Missouri, has deposited in the John Britts Owen collection a poorly preserved specimen (number 618) from the Graydon Springs sandstone (Cherokee) near Springfield, Missouri, which is clearly referable to the genus *Domatoceras* and which may represent the species under consideration. Unfortunately this specimen is so poorly preserved and incomplete that its specific affinities can not be determined with any degree of certainty.

Occurrence.—All of the representatives of this species we are studying came from the Cherokee of Missouri; most of them (including all of the figured specimens) came from immediately above the Tebo coal in Henry County, but three of them came from immediately above an unnamed local coal 10-15 feet below the Jordan coal in the England strip pit (sec. 17, T. 41 N., R. 25 W.) in Henry County, and another came from immediately above the Rich Hill coal (near the middle of the Cherokee) about 1½ miles northeast of Arthur, Vernon County, Missouri, that is, from a strip pit located in the NW¼NW¼ sec. 4, T. 37 N., R. 31 W.

Repository.—All but one of the specimens we are studying (cotypes) are in the private collection of John Britts Owen, Clinton, Missouri, where they are numbered 563-581, inclusive; the other cotype (the one from above the Rich Hill coal in Vernon County, Missouri) is number 676 in the paleontological collections of the State University of Iowa. The figured specimens are numbered as follows: 563 (plate XVIII, figure 1), 564 (plate XVII, figures 2-4), 565 (plate XVII, figure 1), and 566 (plate XVI, figure 4). The two specimens from below the Jordan coal in Henry County, Missouri, are numbered 567.

Genus SOLENOCHILUS Meek and Worthen 1870

SOLENOCHILUS CAPAX (Meek and Worthen)

1865. *Nautilus (Cryptoceras) capax* Meek and Worthen, Acad. Nat. Sci. Philadelphia Proc., p. 262.

1875. *Nautilus (Cryptoceras) capax* Worthen and Meek, Illinois Geol. Survey, vol. 6, p. 532, pl. 33, figs. 1, 1a.

1891. *Asymptoceras capax* Hyatt, Texas Geol. Survey Ann. Rep. 2, pp. 346, 347.
1893. *Solenocheilus capax* Hyatt, Texas Geol. Survey Ann. Rep. 4, p. 460.
1898. *Asymptoceras capax* Weller, U. S. Geol. Survey Bull. 153, p. 101.
1933. *Solenochilus capax* Miller, Dunbar, and Condra, Nebraska Geol. Survey Bull. 9, ser. 2, p. 230.

The holotype and only known representative of this species has been well described and illustrated by Worthen and Meek, and since their publication is readily available to most geologists there is no need for us to duplicate this work. The broad conch and the ventral siphuncle of this form clearly indicate that it should be referred to *Solenochilus,* the genotype of which is *S.* [*Nautilus* (*Cryptoceras*)] *springeri* (White and St. John) of the Upper Pennsylvanian of Adair County, Iowa. Meek and Worthen referred this species to *Cryptoceras* d'Orbigny 1850, but that name is invalid as it is a homonym of *Cryptoceras* Barrande 1846—it is to be supplanted by *Solenochilus* Meek and Worthen 1870.

In 1891 Hyatt referred this species to *Asymptoceras* Ryckholt 1852 and stated that he believed that *Solenochilus* should be suppressed as a synonym of *Asymptoceras,* the genotype of which is *A.* [*Nautilus*] *cyclostomum* (Phillips) of the Lower Carboniferous of England and Ireland and possibly Belgium and Russia. However, by 1893 Hyatt had become aware of the fact that the genotype of *Solenochilus* is not congeneric with that of *Asymptoceras,* and he therefore recognized the validity of both genera; this conclusion he expressed again in 1900 in the Zittel-Eastman *Text-book of Palaentology* (p. 525), which was the last time he dealt with these genera. In 1893 he apparently believed that the species under consideration, *S. capax,* should be referred to the genus *Solenochilus.*

Occurrence.—Cherokee at Charboniere, Saint Louis County, Missouri.

SOLENOCHILUS NEWLONI (Hyatt)

Text figures 7A, 7B

1891. *Asymptoceras Newloni* Hyatt, Texas Geol. Survey Ann. Rep. 2, pp. 346-347, text figures 48, 49.
1893. *Asymptoceras Newloni* Hay, Kansas Acad. Sci. Trans., vol. 13, p. 45.
1904. *Asymptoceras newloni* Beede and Rogers, Kansas Univ. Sci. Bull., vol. 2, no. 15, pp. 461, 463.

No representative of this species other than the holotype has ever been found. Hyatt described the holotype as follows:

"The species in hand is a fragment very similar to *As.* (*Cryptoceras*) *capax*, Meek and Worthen.[45] There are three air chambers incompletely preserved in the cast. The last two sutures are 17 mm. apart on the venter. The increase in size is very rapid, being as much as 46 mm. in the greatest transverse diameter to 68 mm., a difference of 22 mm. in a distance of only 51 mm., as measured along the centre of the venter, and only 35 mm. as measured along the side of the whorl.

"These measurements show a more rapid increase than in the whorl of *Asympt. capax*. The sutures are not only wider apart than in that species, but the form of the whorl also differs. In the figure of *As. capax* the greatest diameter of the living chamber is above or external to the umbilical shoulder, whereas in this species it is at the umbilical shoulder. The sides converge outwards from these shoulders and are not gibbous as in *capax*, and in the living chamber, which is evidently very nearly complete on one side, the whorl becomes flatter or more depressed on the abdomen than in *capax*, and the flaring of the aperture at the umbilical shoulders carries the lateral angles out with great rapidity. The diameter through the widest part of the whorl at the last suture is 68 mm., at a point about half way between this and the aperture about 82 mm., through the wings themselves not less than 120 mm., and perhaps a little more in perfect specimens.

"The sutures have a distinct but very shallow broad lobe on the venter, which is irregularly interrupted by the siphon, and there are also shallow lateral lobes. In some specimens the sutures are very likely continuous, as they are in the figure of *capax*. If the side view of the sutures in the figure of *capax* is correct, these differ decidedly from those of this species. This shell differs from *Asym. Springeri* in having less angular umbilical shoulders, a more depressed abdomen, and more convergent sides. In fact, *Springeri* and *capax* resemble each other more than either of them resemble this species.[46]

[45] A. H. Worthen and F. B. Meek: Descriptions of invertebrates. Illinois Geol. Survey, vol. 6, 1875, p. 532, pl. 33, figs. 1, 1a.

[46] "The species has been dedicated to Dr. W. S. Newlon, of Oswego, who found and sent the specimen, with some others described in this paper, to the National Museum."

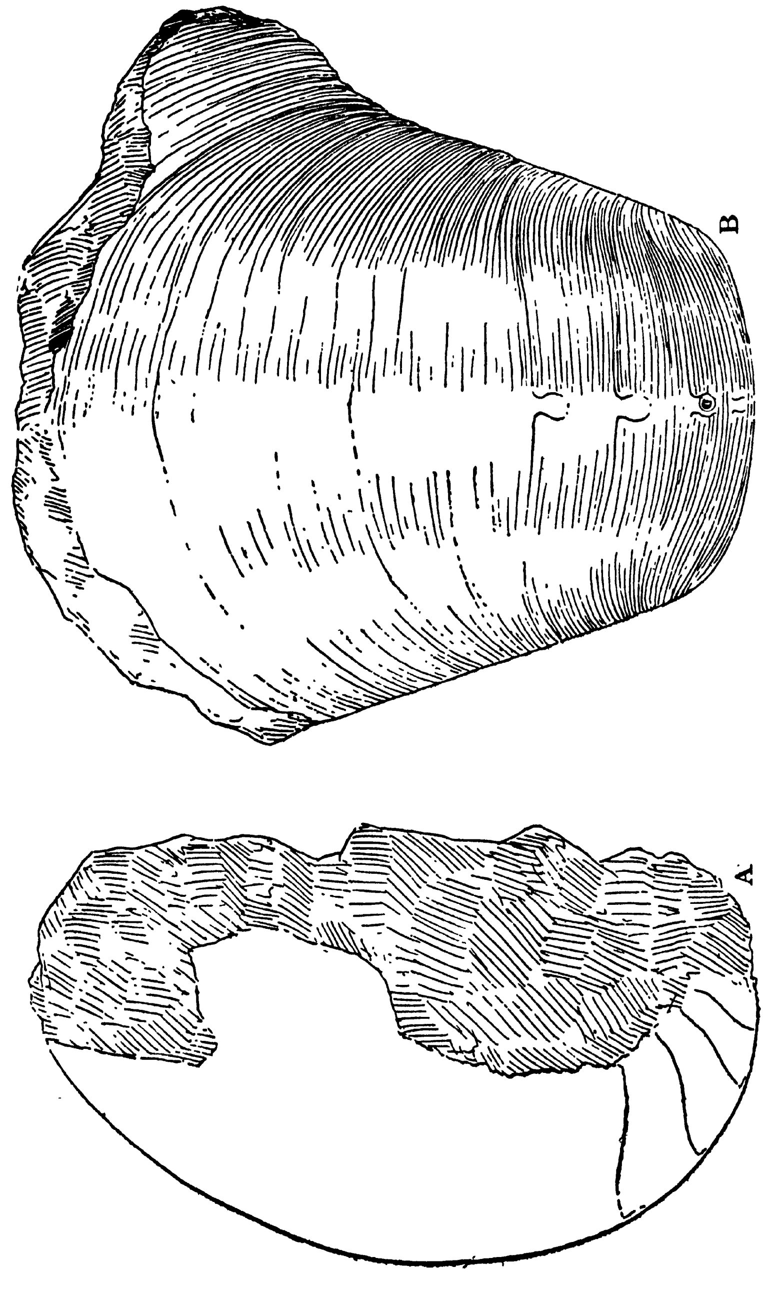

Figure 7.—Two views of the holotype of *Solenochilus newloni* (Hyatt), x 9/10; from immediately above the Lexington coal (Cherokee), near Oswego, Kansas. After Hyatt.

"The comparative length of living chamber can not be given, since the inner whorls were not visible."

Remarks.—This species is not very similar to most of the forms that are now generally referred to *Solenochilus*, but it appears to be more closely related to the type of that genus, *S. springeri* (White and St. John) of the Upper Pennsylvanian of Iowa, than to the type of *Asymptoceras*, *A. cyclostomum* (Phillips) of the Lower Carboniferous of England and possibly Ireland, Belgium, and Russia. It is strikingly similar to the specimen described below as *Solenochilus peculiare*, but it differs from that form in that its sutures form lobes rather than saddles as they cross the venter.

Occurrence.—Hyatt states only that the holotype came from the "Coal Measures" of Oswego, Kansas. However, Beede and Rogers state that it came from a strip pit one and one-half miles southeast of Oswego, and Professor R. C. Moore[47] has recently written us that "that is doubtless the horizon of the Lexington coal, which occurs immediately below the lower Fort Scott and we should place it in the very top of the Cherokee shale."

Repository.—Hyatt states that the holotype is in the U. S. National Museum.

SOLENOCHILUS PECULIARE Miller and Owen, n. sp.

Plate XIX, figures 1, 2

This species is being based on a single specimen which is rather incomplete but which is so distinct from all known forms that conspecific specimens can be readily identified. The holotype is an internal mold of the ventral portion of the adoral six camerae of the phragmacone and the adjacent portion of the living chamber. When complete, it was subglobose in shape and it attained a maximum diameter of at least 135 mm. and a maximum width of at least 85 mm. The conch apparently was strongly depressed dorsoventrally and it was broadly rounded ventrally and laterally.

The internal mold of the phragmacone of the holotype is longitudinally lirate—the lirae are very fine and rather closely spaced but they are not very prominent. There is also a small low rounded ridge or raised line along the venter of the entire specimen.

The camerae are about one-fourth or one-fifth as long as the conch

[47] Personal communication, dated February 3, 1934.

is wide, but those of the holotype become progressively shorter orad and the extreme adoral camerae are very short—this indicates that the specimen represents a late mature or gerontic individual. Each suture forms a low broad shallow broadly rounded ventral saddle and on either side of it a similar lobe, a similar but slightly broader ventro-lateral saddle, and a broad very shallow scarcely recognizable lateral lobe which presumably is followed by a saddle on the umbilical shoulder.

The siphuncle is relatively small and it is ventral and marginal in position and apparently was in contact with the ventral wall of the phragmacone. The preservation of the siphuncle of the holotype is not all that could be desired, but apparently its structure is very unusual. The septal necks are about two-fifths as long as the camerae. They appear to be somewhat expanded a short distance apicad of the septa and then rather abruptly contracted near their adapical ends. The connecting rings appear to be pyriform in shape, that is, they appear to be contracted rather abruptly near their adoral end and rather gradually near their adapical end. The maximum diameter attained by the connecting rings exceeds that attained by the septal necks. The segments of the siphuncle appear to bear a sharp subangular transverse constriction at the junction of the septal necks and the connecting rings. There is a suggestion of a transverse partition across the siphuncle at this constriction.

Remarks.—The above-described form is closely similar to only *Solenochilus newloni* (Hyatt) of the uppermost Cherokee (Lexington coal horizon), near Oswego, Kansas. Hyatt's figures of the type specimen of that species show that at least the connecting rings of the siphuncle of *S. newloni* are strikingly similar to those of *S. peculiare*. The sutures of *S. newloni* form lobes rather than saddles as they cross the venter and this character serves to differentiate the two species. It may be that because of their relatively narrow conchs and peculiar siphuncles these two forms should not be placed in the same genus with most of the species that have been referred to *Solenochilus*, but it does not seem feasible to eliminate them from that genus at present, particularly when so little information is available in regard to the genotype.

Occurrence.—Holotype and only known representative of this species came from an unnamed limestone member of the Cherokee

formation, 10-15 feet below the Jordan coal, England strip pit (sec. 17, T. 41 N., R. 25 W.), Henry County, Missouri.

Repository.—Private collection of John Britts Owen, Clinton, Missouri, No. 508.

PLATES VIII-XIX

PLATE VIII

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Figures 1-4.—*Brachycycloceras longulum* Miller and Owen, n. sp. 208

1.—Lateral view (unretouched photograph) of the longest of the cotypes, x 2; from immediately above the Tebo coal (Cherokee), Henry County, Missouri.

2-4.—Lateral and septal views of another of the cotypes, x 2, and enlarged view (unretouched photograph, x 8) of the adoral median portion of the same specimen showing the details of the surface markings of the test; from immediately above the Lexington coal (Cherokee), Henry County, Missouri.

Figure 5.—*Bactrites? cherokeensis* Miller and Owen, n. sp. 206

Septal (apical) view of the holotype, x 1; from below the Jordan coal (Cherokee), Henry County, Missouri. See also figure 3 on plate X.)

Figure 6.—*Pseudorthoceras knoxense* (McChesney) 196

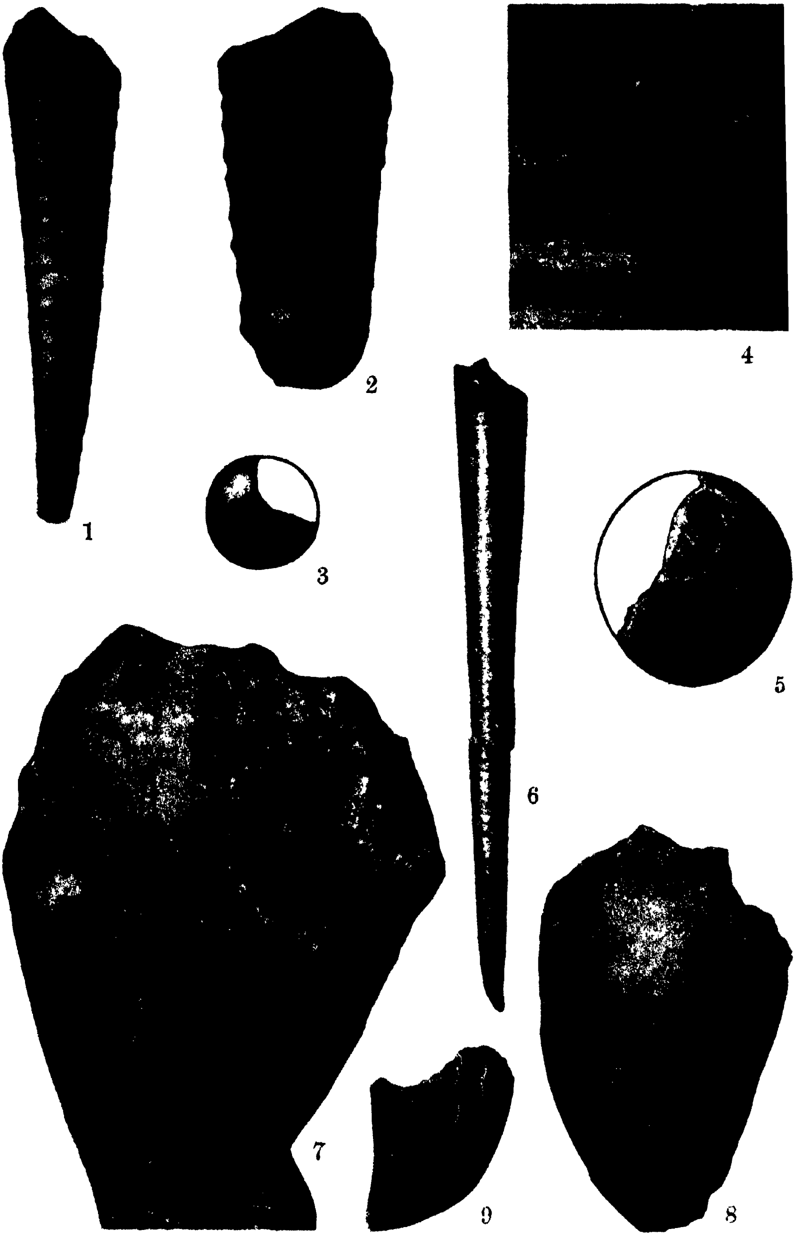
Lateral view (unretouched photograph, x 2) of a typical specimen showing the characteristic curvature of the extreme adapical portion of the conch; from immediately above the Tebo coal (Cherokee), Henry County, Missouri.

Figures 7-9.—*Poterioceras bransoni* Miller and Owen, n. sp. 199

7.—Ventro-lateral view of one of the paratypes, x 1; from immediately above the Tebo coal (Cherokee), Henry County, Missouri.

8.—Ventro-lateral view (unretouched photograph, x 2) of another of the paratypes, showing the transverse growth lines on a fragment of the test that adheres to the internal mold; from immediately above the Lexington coal (Cherokee), Henry County, Missouri.

9.—Lateral view (unretouched photograh, x 2) of a small specimen representing only the extreme adaptical portion of the conch; from immediately above the Lexington coal (Cherokee), Henry County, Missouri. (See also figure 1 on plate IX.)



Miller and Owen, Cherokee Nautiloids

Miller and Owen, Cherokee Nautiloids

PLATE IX

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Figure 1.—*Poterioceras bransoni* Miller and Owen, n. sp. 199
Ventro-lateral view (x 3/5) of the holotype—the venter is on the reader's left—from immediately above the Lexington coal (Cherokee), Henry County, Missouri. (See also figures 7-9 on plate VIII.)

PLATE X

Plate X

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Miller and Owen, Cherokee Nautiloids

Miller and Owen, Cherokee Nautiloids

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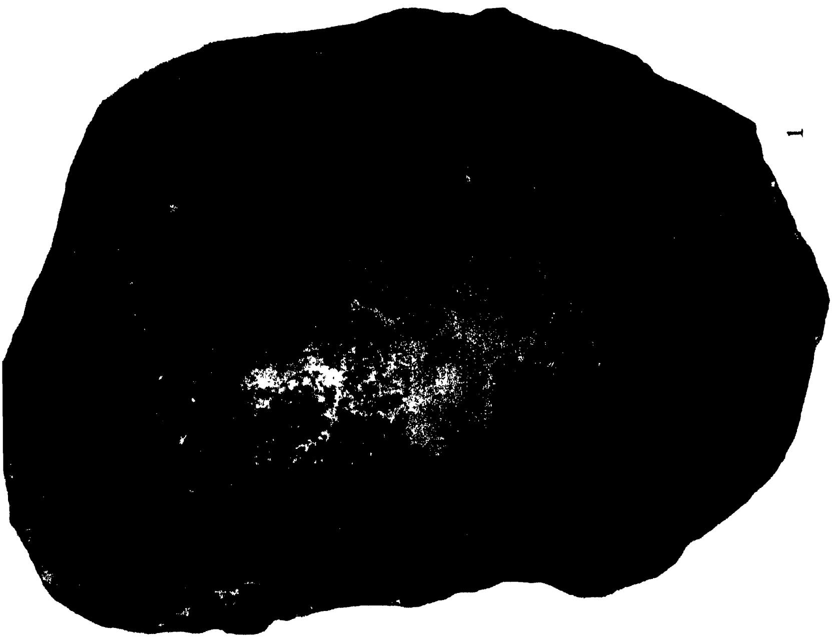

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Miller and Owen, Cherokee Nautiloids

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Miller and Owen, Cherokee Nautiloids

PLATE XVIII

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Figure 1.—*Domatoceras williamsi* Miller and Owen, n. sp. 246

Lateral view of one of the cotypes, a large, nearly complete internal mold, x 1; from immediately above the Tebo coal (Cherokee) in the Vansant strip pit (sec. 22, T. 41 N., R. 27 W.), Henry County, Missouri. (See also figure 4 on plate XVI and figures 1-4 on plate XVII.)

PLATE XVII

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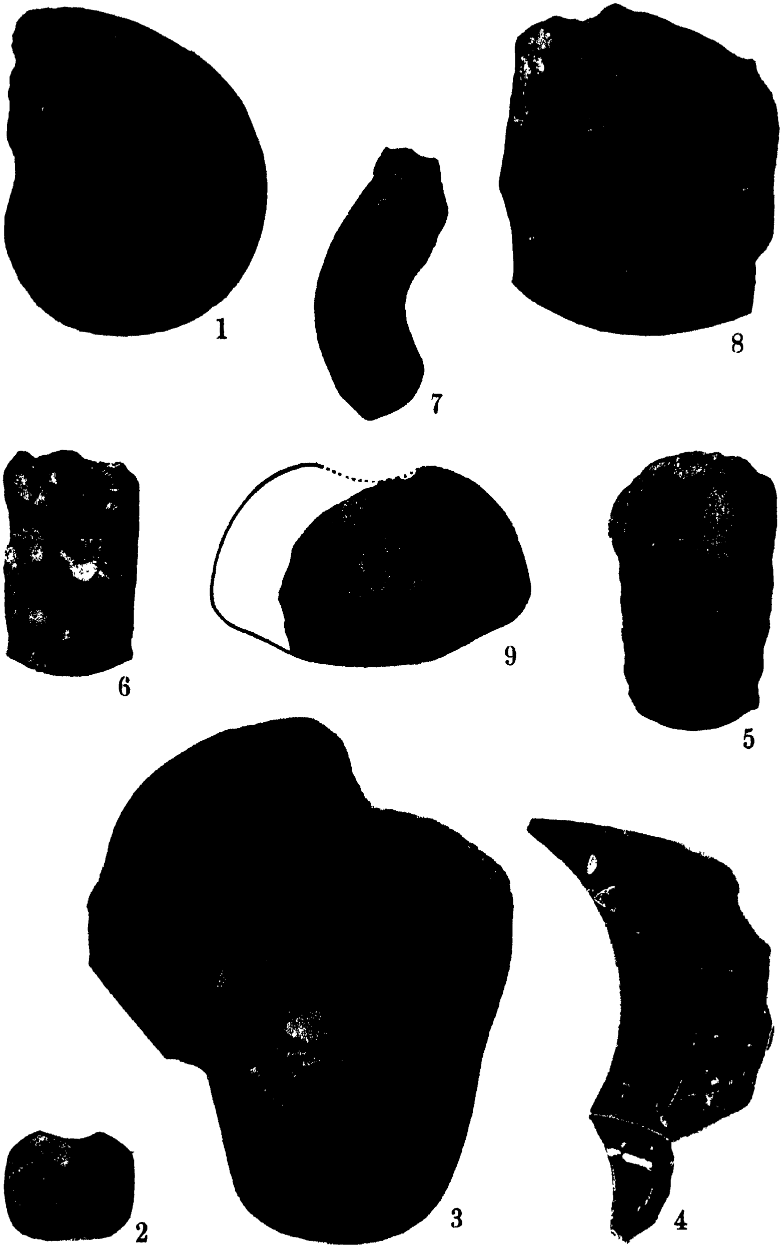
1.—Lateral view of one of the cotypes, a large testaceous specimen, showing the ventro-lateral nodes on the adoral half of the outer volution and the dorso-lateral nodes or short ribs on the adoral fourth of the outer volution, x 1; from imediately above the Tebo? coal (Cherokee), in the Bowens mine near Windsor, Henry County, Misouri.

2-4.—Lateral, ventral, and septal views of another of the cotypes, a well-preserved internal mold, x 1; from immediately above the Tebo coal (Cherokee) in the Vansant strip pit sec. 22, T. 41 N., R. 27 W.), Henry County, Missouri. Figures 2 and 3 are unretouched photographs. Figure 4 represents the antepenultimate septum. A diagramatic representation of one of the adoral sutures of this specimen is given as text figure 6 on page 248. (See also figure 4 on plate XVI and figure 1 on plate XVIII.)

Miller and Owen, Cherokee Nautiloids



Miller and Owen, Cherokee Nautiloids

PLATE XVI

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Figures 1,2.—*Metacoceras mutabile* Miller and Owen, n. sp. 226

1.—Lateral view (unretouched photograph) of the holotype, slightly more than x 1; from immediately above the Tebo coal (Cherokee), Henry County, Missouri.

2.—Cross section of the living chamber of a paratype, x 1; from immediately above the Tebo coal (Cherokee), Henry County, Missouri.

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Ventral view of a rather fragmentary specimen, x 2; from immediately above the Tebo coal (Cherokee), Henry County, Missouri.

Figure 4.—*Domatoceras williamsi* Miller and Owen, n. sp. 246

Mediam longitudinal dorso-ventral section (unretouched photograph) of part of two volutions of a typical specimen showing the structure of the siphuncle, x 2; from immediately above the Tebo coal (Cherokee), in the Tillman strip pits (NE¼NE¼ sec. 23, T. 42 N., R. 26 W.), Henry County, Missouri. The connecting rings are not preserved in the adoral camera of the outer volution but the septal necks are very distinct there. (See also figures 1-4 on plate XVII and figure 1 on plate XVIII.)

Figures 5-7.—*Metacoceras biseriatum* Miller and Owen, n. sp. 229

Ventral, apical, and lateral views (unretouched photographs) of the holotype, x 1; from immediately above the Lexington coal (Cherokee), Henry County, Missouri.

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Ventral and septal views (unretouched photographs) of a fragment of a large representative of the genus *Metacoceras,* x 1; from immediately above the Tebo coal (Cherokee), Henry County, Missouri.

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Figures 1-5.—*Parametacoceras bellatulum* Miller and Owen, n. sp. 223

1-3.—Three views of the holotype, x 2; from immediately above the Lexington coal (Cherokee), Henry County, Missouri. Figures 2 and 3 are unretouched photographs.

4.—Septal view (unretouched photograph) of a paratype, an early mature specimen, x 2; from immediately above the Lexington coal (Cherokee), Lafayette County, Missouri.

5.—Lateral view (unretouched photograph) of another paratype showing the details of the surface ornamentation, x 2; from immediately above the Lexington coal (Cherokee), Henry County, Missouri.

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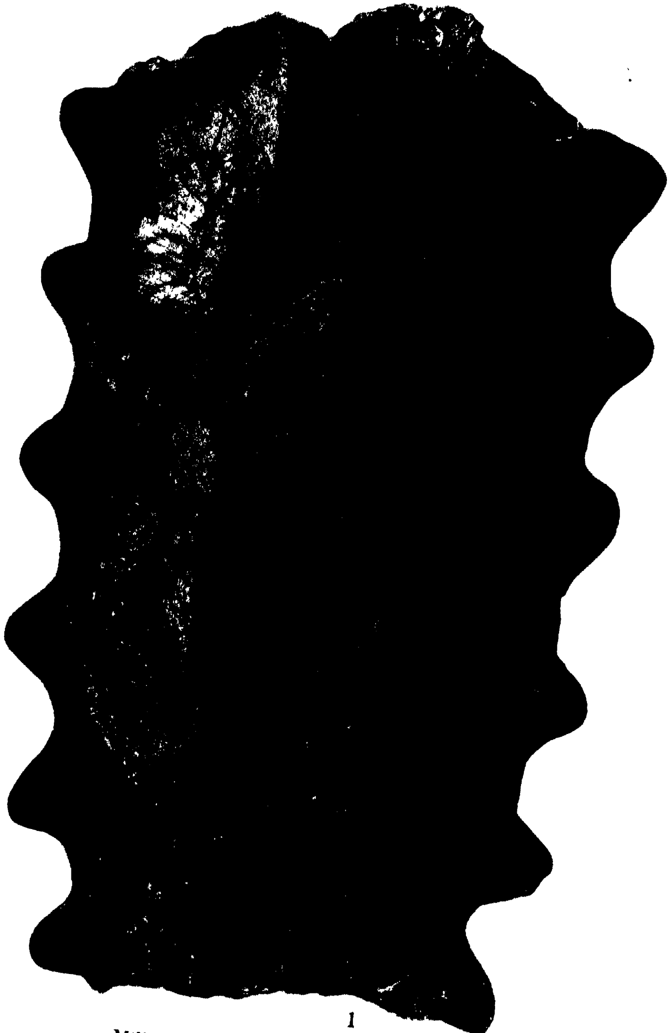
Ventral, lateral, and apical views of the holotype, x 2; from immediately above the Tebo coal (Cherokee), Henry County, Missouri. Figures 6 and 7 are unretouched photographs.

Miller and Owen, Cherokee Nautiloids



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Miller and Owen, Cherokee Nautiloids

PLATE XIV

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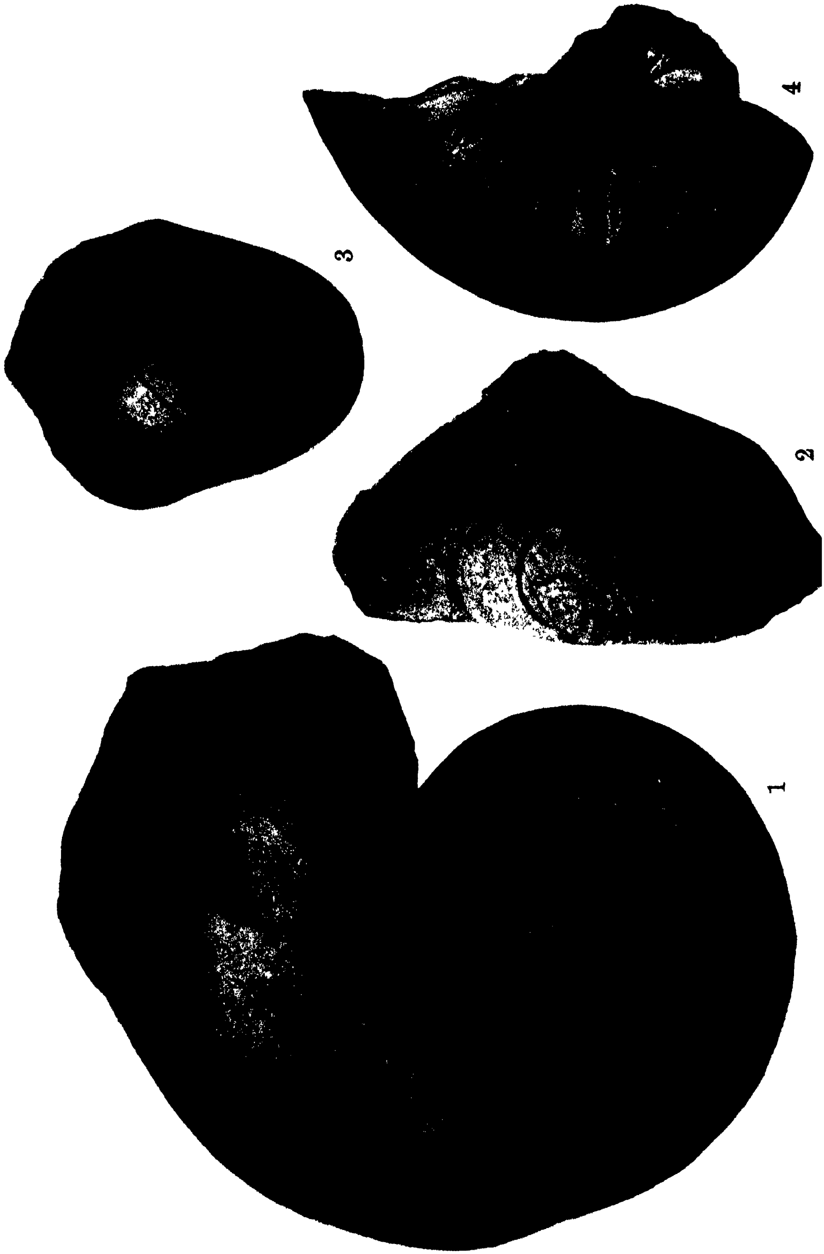
Figure 1. *Temnocheilus harneri* Miller and Owen, n. sp. 223
Ventral view of the paratype, x 1; from immediately above the Rich Hill coal (Cherokee), near Arthur, Vernon County, Missouri. (See also figure 1 on plate XIII.)

PLATE XIII

Miller and Owen, Cherokee Nautiloids



Miller and Owen, Cherokee Nautiloids

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Ventral and lateral views, x 2, of two specimens from immediately above the Tebo coal (Cherokee), Henry County, Missouri.

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1.—Lateral view of a large specimen, x 3/7; from immediately above the Tebo coal (Cherokee), Vansant srip pits (sec. 22, T. 41 N., R. 27 W.), Henry County, Missouri.

2. Ventral view (unretouched photograph) of a typical specimen, x 1; from immediately above the Tebo coal (Cherokee), West Missouri Power Company strip pits (sec. 9, T. 42 N., R. 26 W.), Henry County, Missouri.

3-6.—Dorsal, ventral, and septal views, x 2, and longitudinal dorsal-ventral section, x 4, of a typical specimen; from immediately above the Tebo coal (Cherokee), Carroll strip pits (sec. 9, T. 42 N., R. 25 W.), Henry County, Missouri. All four of these illustrations are unretouched photographs.

Figures 7,8.—*Mooreoceras normale uniconstrictum* Miller and Owen, n. sp... 204

Lateral and septal views of the holotype, x 2; from immediately above the Tebo coal (Cherokee), Shaw strip pit (sec. 23, T. 42 N., R. 26 W.), Henry County, Missouri. Figure 7 is an unretouched photograph. Figure 8 represents the adapical end of the living chamber.

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Figures 1,2.—*Solenochilus peculiare* Miller and Owen, n. sp. 254

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Asterisks refer to illustrations.

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The Fusulinids of the Des Moines Series of Iowa

by

M. L. THOMPSON

Published by the University, Iowa City, Iowa
1934

CONTENTS

The Fusulinids of the Des Moines Series of Iowa[1]

INTRODUCTION

In 1932 the Iowa Geological Survey inaugurated an extensive study of the Pennsylvanian system of Iowa under the direction of Dr. A. C. Tester. Detailed stratigraphic studies were begun by Mr. D. G. Stookey of the State University of Iowa, and I undertook the paleontological portion of the work. All the fusulinids described below were obtained by me during the summer field-season of 1932 and 1933 from the Des Moines series of southeastern Iowa. Samples were collected from every fossiliferous horizon and locality found east of Lucas and Appanoose counties, and the collections obtained are believed to be fairly complete.

The rapid evolution, the wide geographic distribution, and the excellent state of preservation of large numbers of the shells of these foraminifera are rapidly being demonstrated, and the value of this group of fossils for detailed correlation over wide areas as well as within restricted regions is fast becoming recognized. Although the Upper Carboniferous Fusulinidae of Europe and Asia have long received a great deal of attention, it is only within recent years that American forms have been given the consideration they merit. Modern American studies were inaugurated by the well-known monograph of Dunbar and Condra, which is concerned chiefly with middle and upper Pennsylvanian forms. Our knowledge of the biologic nature of the fusulinids is rapidly increasing and specific characters are becoming more and more clearly understood.

With the exception of some representatives of *Wedekindellina euthysepta* described below, all of the Iowa species which I am referring to the genus *Wedekindellina* were obtained from a thin calcareous shale member of the middle portion of the Cherokee, about 1½ feet below a thin limestone, 35 feet below the White

[1] Published by permission of the Director of the Iowa Geological Survey.

Breast coal.[2] *W. euthysepta* occurs also in an 8 inch shale bed located about 8 feet above the White Breast coal between two thin limestones. Associated with these species of *Wedekindellina,* especially in the lower horizon, are many representatives of the genus *Fusulina* s.s.—this genus ranges throughout the remaining upper part of the Des Moines series. My study of these fusulinids indicates that the White Breast coal of Iowa is the stratigraphic equivalent of the so-called Coal No. 2 of the Liverpool formation of Illinois; that the fusulinid-bearing calcareous shale approximately 35 feet below the White Breast coal is very closely similar in age to the Stonefort limestone of the Tradewater formation of southern Illinois; that the so-called "eighteen-foot limestone" [18 feet above the Mystic coal] is the approximate stratigraphic equivalent of the "roof-rock" of Coal No. 6 of Illinois; and that the so-called "fifty-foot limestone" [50 feet above the Mystic coal] of Iowa is not greatly different in age from the Pawnee limestone of Kansas. Only one species is known from Iowa that is referable to the genus *Fusulinella, F. iowensis,* n. sp. It came from near the base of the Cherokee in a limestone which forms the cap of an unnamed coal that is rather extensively mined in Jefferson and Davis counties; this coal lies about 20 feet above the Mississippian limestone in southern Jefferson County and about 90 feet below the White Breast coal.

I wish to take this opportunity to acknowledge my indebtedness to Dean George F. Kay, Director of the Iowa Geological Survey, who has promoted and encouraged this study and has made possible the necessary field work; to Professor C. O. Dunbar who has read the entire manuscript and has made many valuable criticisms; and to Dr. A. K. Miller whose continued interest and advice were especially helpful.

SYSTEMATIC PALEONTOLOGY

Genus Wedekindellina Dunbar and Henbest

This genus was established by Dunbar and Henbest[3] in 1930 under the name *Wedekindella* with *Fusulinella euthysepta*[4] Hen-

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[2] Name given by Lugn in 1927 in his report on the Geology of Lucas County, Iowa, in the Iowa Geological Survey, volume 32, pp. 105-237.

[3] Dunbar, C. O., and Henbest, L. G., The fusulinid genera *Fusulina, Fusulinella* and *Wedekindella*: *Am. Jour. Sci.*, ser. 5, vol. 20, pp, 357-364, 1930.

[4] The specific name was originally spelled "euthusepta," but Professor C. O. Dunbar has kindly pointed out to me that Article 19 of the International Rules

best as the genotype, and with only one other species, *Boultonia rawi* Lee, referred to it. The name *Wedekindella* was preoccupied and the original authors[5] proposed in 1931 to rename the genus *Wedekindia*; this name was also preoccupied and in 1933 the genus was given a new name, *Wedekindellina,* by its original establishers.[6] My concept of the genotype of *Wedekindellina, Fusulinella euthysepta,* is based on Henbest's original description and illustrations[7] (Henbest's pl. 8, figs. 6, 8, 8a, and 8b; and pl. 9, fig. 1, but not pl. 8, fig. 7, and pl. 9, figs. 2 and 5).

The validity of the genus *Wedekindellina* has been recognized by some students of Fusulinidae but by others the name has been placed in synonymy with other genera. It seems to me that forms of the type of *Fusulinella euthysepta* are so markedly different from those referable to well established genera that they should be recognized as representing a distinct genus; I would place the following American forms in *Wedekindellina*: *Fusulinella minuta* Henbest of the Tradewater formation of Illinois; *Wedekindella excentrica* Roth and Skinner, *W. excentrica magna* R. and S., *W. coloradoensis* R. and S., *W. coloradoensis perforata* R. and S. of the McCoy formation of Colorado; *Wedekindia henbesti* Skinner of the Cherokee of Oklahoma; and the forms from the Cherokee of Iowa described below as *Wedekindellina dunbari, W. elfina,* and *W. uniformis.* As can be seen from this list, the genus *Wedekindellina* is widespread in North America, and further study will most probably reveal even a greater geographic distribution; however its stratigraphic range is limited and representatives of it are not known to occur in beds younger than the Cherokee nor in beds older than the middle of the Atoka of Oklahoma.

On the basis of the original description and illustrations of the genotype, the specimens available for study, and the illustrations and descriptions of the species listed above, I have drawn up the following generic diagnosis of *Wedekindellina*: Shell small, subfusiform to fusiform, slender, elongate; mature specimens usually do not exceed 5 mm in length and 2 mm in width; form ratio of

of Zoological Nomenclature and Opinion 36 permitted him and Mr. Henbest to change the spelling to "*euthysepta*".

5 Dunbar, C. O., and Henbest, L. G., *Wedekindia,* a new fusulinid name: *Amer. Jour. Sci.,* ser. 5, vol. 21, p. 458, 1931.

6 Dunbar, C. O., and Henbest, L. G., in Cushman, J. A., Foraminifera: *Contr. Cushman Lab. Foram. Research,* Special pub. no. 4, p. 134, 1933.

7 Henbest, L. G., Fusulinellas from the Stonefort limestone member of the Tradewater formation: *Jour. Pal.,* vol. 2, pp. 70-85, pls. 8-10, 1928.

mature specimens 1:2.5 to 1:5.0. Septa unfluted, straight or broadly curved. The septa are composed of four layers: the two outer layers (anterior and posterior) are tectoria and are thicker near the base and thinner near the top of the septa where they continue onto the "floors" and "roofs" of the chambers to form the upper and lower tectorium respectively of the spirotheca; the anterior inner layer of the septa is the downward extension to the base of the septa of the tectum of the spirotheca; and the posterior inner layer is the downward continuation of the diaphanotheca of the spirotheca which may or may not extend entirely to the base of the septa. The spirotheca is composed of four layers: an upper very thick rather dense tectorium which is underlain by a still more dense and very thin layer, the tectum; a basal layer, tectorium, that is rather dense and thin and is overlain by a lighter and thicker layer, the diaphanotheca. The upper tectorium thickens rapidly from beyond the limits of the chomata to completely fill the chambers in the polar regions in all volutions except, in some forms, the inner one or two and/or the outer one or two. Proloculum small; tunnel low and broad and its intersection with axial sections usually irregular; tunnel bordered on either side by well defined asymmetrical ridges, chomata.

Wedekindellina is perhaps more closely related to *Fusiella*[8] than to any other recognized genus. Through the courtesy of Professor J. S. Lee of the National University of Peking I have had an opportunity to examine two of the figured types of *Fusiella typica* Lee and Chen of the Huanglung limestone (Moscovian) of southeast China, the genotype of *Fusiella*, and I concur with these authors in their description of this species. *Fusiella typica* is quite distinct from any other recognized genotype, and no similar form is known from America. Typical representatives of *Wedekindellina* differ from this genotype of *Fusiella* in that their spirotheca is composed of four layers (an upper tectorium, a tectum, a diaphanotheca, and a lower tectorium) whereas the spirotheca of *Fusiella* is composed of only three layers (an upper tectorium, a tectum, and

[8] This genus was established by Lee and Chen (Lee, J. S., Chen, S., and Chu, S., The Huanglung limestone and its fauna: *Mem. Nat. Research Inst. Geol.*, no. 9, p. 107) in 1930, who designated as the genotype *Fusiella typica* L. and C. of the Huanglung limestone (Moscovian) of southeast China. They also included in the genus *Fusiella paradoxa* L. and C. of the Huanglung limestone of southeast China, and stated that *Boultonia rawi* Lee of the Penchi series (Moscovian) of south Manchuria might represent it; however, *B. rawi* more probably is a representative of the genus *Wedekindellina*.

a lower tectorium); the tectum of *Fusiella* probably corresponds to the tectum and diaphanotheca of *Wedekindellina.* Also, representatives of *Fusiella* do not contain the heavy deposits of tectorium that tend to fill the chambers in the axial regions of *Wedekindellina.* In *Fusiella* the shells are shorter and more obese than are those of *Wedekindellina,* and the inner volutions of the two genera are somewhat different.

Representatives of the genus *Wedekindellina* can be readily distinguished from those of *Schubertella* by their much longer axis, smaller form ratio, more numerous volutions, and by the development of the tectorium of *Wedekindellina* that fills the chambers in the polar regions. Representatives of the genera *Fusulina* s. s. and *Fusulinella* are as a rule much larger than are those of *Wedekindellina,* they have fluted septa in at least part of the shell, and they lack the heavy tectorium of the axial regions found in species of *Wedekindellina.* The relation between *Boultonia willsi* Lee, the genotype of *Boultonia* Lee,[9] and typical representatives of *Wedekindellina* seem sufficiently distinct to avoid any possible confusion, for Lee states that the antetheca in *Boultonia* are regularly and gently fluted, and his illustrations show that the axial region does not contain thick deposits of tectorium; also, the stratigraphic range of these two genera is quite different. In his original discussion of *B. rawi,* Lee[10] compared that species with *Fusulina exigua* Schellwien-Staff[11] (not *F. vulgaris exigua* Schellwien-Dyhrenfurth) from

[9] The genus *Boultonia* was proposed by Lee (Lee, J. S., Fusulinidae of North China: *Palaeontologia Sinica,* ser. B., vol. 4, fasc. 1, p. 10) in 1927 and *B. willsi* Lee of the Uralian of South Manchuria was designated as the genotype—only one other species, *B. rawi* Lee of the Moscovian of South Manchuria, was referred to it. *B. rawi* has subsequently been referred by Dunbar and Henbest to *Wedekindellina* and by Lee and Chen to *Fusiella.* In 1930 Galloway and Ryniker (*Oklahoma Geol. Survey,* circular 21, p. 23) and in 1933 Dunbar (in Cushman, J. A., Foraminifera, p. 132) placed *Boultonia* in synonymy with *Schubertella.* The very elongate and slender nature of the shells and the fluted septa of *B. willsi,* the genotype of *Boultonia,* indicates to me that it is generically distinct from the genotype of *Schubertella,* and in 1933 Galloway (A Manual of Foraminifera, p. 400) accepted *Boultonia* as a valid genus.

[10] Lee, J. S., Fusulinidae of North China: *Palaeontologia Sinica,* ser. B., Vol. 4, fasc. 1, p. 12, 1927.

[11] The name *Fusulina exigua* Schellwien-Staff is a homonym of *Fusulina vulgaris exigua* Schellwien-Dyhrenfurth according to Article 36 of the International Rules of Zoological Nomenclature, and the species figured and described by Schellwien-Staff as *Fusulina exigua* and by Dunbar and Condra as *Triticites exiguus* is therefore without a valid name. I propose to call this species *Triticites nebraskensis,* and since the locality and horizon of Schellwien-Staff's specimens was not given I wish to designate the specimens figured and described by Dunbar and Condra (Dunbar and Condra's pl. 8, figs. 1-5) from

Iowa, but he stated that it presented certain differences from the latter. Dunbar and Condra[12] have shown that *F. exigua* Schellwien-Staff has a different wall structure than *B. rawi*, and that it occupies a position much higher stratigraphically than *B. rawi*.

Species of *Wedekindellina* are not as easily distinguished from one another as are those of some of the other genera of the Fusulinidae; this is due largely to their very small size, unfluted septa, and heavy deposits of tectorium which tend to hide the nature of the septa in the polar regions. In my collections from Iowa there are a number of specimens which present certain differences from the forms that are here recognized as distinct species but which I do not feel justified at the present time to establish as types of separate species or varieties. Some of the characters which collectively are recognized to be of specific value are general size of mature specimens, form ratio during ontogenetic development, general outline of the shell, trace of the septa, number of volutions, number of septa per volution, axial fillings of tectorium, etc.

WEDEKINDELLINA EUTHYSEPTA (Henbest) ?

Plate XX, figures 1, 2, 7, 9, 12, 13, 17, 22, 24-27

Fusulinella euthusepta Henbest, *1928*, Jour. Pal., vol. 2, pp. 80-81, pl. 8, figs. 6-8, pl. 9, figs. 1, 2, 5.

(?) *Fusulinella euthusepta* Galloway and Ryniker, *1930*, Oklahoma Geol. Survey, Circular no. 21, pp. 25-26, pl. 5, figs. 6-11.

(?) *Fusulinella euthusepta* Roth, *1930*. Am. Assoc. Petroleum Geologists, Bull., vol. 14, p. 1261.

(?) *Fusulinella euthusepta?* Roth, *1930*, Am. Assoc. Petroleum Geologists, Bull., vol. 14, p. 1274.

(?) *Fusulina euthusepta* White, *1932*, Texas Univ. Bull. 3211, pp. 24-25, pl. 1, figs. 1-3.

Wedekindellina euthysepta Dunbar and Henbest, *1933*, Contr. Cushman Lab. Foram. Research, Special Pub. no. 4, p. 134, Key, pl. 10, figs. 13-15.

Shell minute, long, slender, and fusiform, with sharply pointed poles. Mature specimens of 7½ to 8 volutions measure 2.77 to 3.54

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the Avoca limestone, Richfield Quarry, 2½ miles south of Richfield, Nebraska, as the types of *Trititicites nebraskensis*.

[12] Dunbar, C. O., and Condra, G. E., The Fusulinidae of the Pennsylvanian System in Nebraska: *Nebraska Geol. Survey* Bull. 2, ser. 2, pp. 111-113, pl. 8, figs. 1-5, 1927.

mm in length and 0.62 to 0.73 mm in width. Axis of coiling usually straight but in some specimens slightly irregular. The rate of decrease of the form ratio is rather uniform throughout growth as is shown by the form ratio of about 1:3.4 in the third volution, 1:3.7 in the fourth volution, 1:4.0 in the fifth volution, 1:4.5 in the sixth volution, and 1:4.5 to 1:5.0 in mature individuals. The surface is smooth to irregular, and in some of the specimens the central portion is markedly inflated.

The septa are rather thick. That part of the anterior tectorium which is adjacent to the tectum is about equal in density to the diaphanotheca on the opposite side of the tectum, but it seems to be disconnected, at least in structure, with the diaphanotheca of the spirotheca of the succeeding chamber; this lighter part measures about 3.9 microns about midway between the center and the poles in the seventh volution. Measurements taken about halfway between the center and the poles in the seventh volution give thicknesses for the anterior tectorium 7.8 microns, for the diaphanotheca 9.8 microns, and for the posterior tectorium 5.8 microns. The external furrows are straight to sinuous and the septa are unfluted.

The proloculum is oval to irregular in shape and the diameter measures between 30 and 45 microns with the maximum diameter apparently parallel to the axis of coiling. The successive volutions develop with uniform increase in the height of the antetheca, and the number of septa increase rather rapidly in the first four volutions and then remain fairly constant in the remaining volutions. The septal count of a sagittal section of a typical specimen is 10 for the first volution, 12 for the second volution, 16 for the third volution, 20 for the fourth volution, 22 for the fifth volution, 22 for the sixth volution, and 23 for the seventh volution.

The four layers of the spirotheca or wall are not easily distinguishable in all parts of the sections. The upper tectorium may be divided into an upper very dense part and a lower much clearer part; the lower part is about one-third as thick as the upper part. The diaphanotheca is only slightly, if any, less dense than the lower part of the upper tectorium. The lower tectorium is very dense, and in some chambers it seems to be exceedingly thin or even absent. The thicknesses of three of the four layers of the spirotheca, measured in the seventh volution just beyond the limits of the chomata and beginning at the upper side, are: upper tectorium 10.0 microns, diaphanotheca 7.8 microns, and lower tectorium 4.0

microns. The upper tectorium, combined with the lower parts of the tectoria of the septa, completely fills all chambers in the polar regions in all volutions except the last chambers of the last volution. In most parts of the sections the spirotheca appears as a rather thick layer bordered on both sides by thinner darker layers and containing near its center a very dark line.

The cross section of the tunnel is very low and elongate; it is about one-fourth as high as the septa and about one-sixth as high as long. The line of intersection of the tunnel with sagittal sections is irregular and the tunnel angle measures about 23 to 30 degrees. The tunnel is bordered on either side by an asymmetrical ridge with a sharply rounded crest which is about one-half the height of the chambers and about twice as wide as high. The floor of the tunnel is covered by a material about equal to the lower part of the upper tectorium in density and thickness, and this layer is higher in the center of the tunnel than near its borders.

The specimens that I am referring with question to this species are quite variable and all of them may not be conspecific. They seem to be divisible into two general types or groups but neither of these is precisely similar with Henbest's figured cotypes of *W. euthysepta*. The specimens represented by figures 1, 2, 9, 17, and 22 on plate XX illustrate one of these groups which is characterized by a long slender uniform shell, a large tunnel angle, and straight external furrows. The specimens represented by figures 7, 12, 13, and 24-27 on plate XX illustrate the second of my groups which is characterized by long slender irregular shells which are distinctly inflated in the central portion, and by very irregular external furrows. In the figure cotypes of *W. euthysepta,* which come from approximately the same horizon as my forms, the shell, though long and slender, has a larger form ratio than any of my specimens and it is larger at maturity and has a greater number of volutions. It seems to me rather doubtful if all of the specimens from Oklahoma, Texas, South Dakota, and Colorado that Galloway and Ryniker, White, and Roth have referred to *W. euthysepta* are conspecific with the figured cotypes of that species, but I can not express a definite opinion in regard to their specific affinities without having an opportunity to examine either the cotypes or the Oklahoma, Texas, South Dakota, and Colorado specimens.

Occurrence.—Specimens which I am referring with question to this species have been found very abundantly in a calcareous shale

immediately below a thin limestone ledge approximately 35 feet below the White Breast coal in the west road-ditch on the east line of Lucas County, Iowa, near the top of a north-sloping hill, east center SE¼ sec. 1, T. 73 N., R. 20 W. (pl. XX, figs. 2, 7, 9, 12, 13, 17, 24-27); from the same horizon on the south bank of a west-flowing creek, 10 feet above the creek bed, 75 yards south of County road L, ½ mile west of Lovilia, Monroe County, Iowa, NE¼SW¼ sec. 10, T. 73 N., R. 18 W. (pl. XX, fig. 22); and sparingly from a shale between two thin limestone layers 8 feet above the White Breast coal, in the bed of a small creek in the southeast corner NE¼ sec. 10, T. 70 N., R. 11 W., Van Buren County, Iowa (pl. XX, fig. 1). The cotypes came from the Tradewater formation of southern Illinois; also Galloway and Ryniker have referred specimens to this species from the Atoka formation of Oklahoma, White referred specimens to this species from the Millsaps formation of Texas, and Roth referred specimens to this species from beds of Cherokee age of South Dakota and Colorado.

Repository.—State University of Iowa, Catalogue Nos. 975-982, 990-995; the figured specimens are Nos. 990, 992-994, 978-982.

WEDEKINDELLINA DUNBARI Thompson, n. sp.

Plate XX, figures 3, 6, 15, 16, 20, 21

Shell minute, elongate, uniformly fusiform; poles sharply pointed; external furrows faint. Mature specimens of 8 volutions are 2.85 to 3.0 mm in length and 0.71 to 0.80 mm in width. The form ratio is about 1:3.2 in the third volution, 1:3.4 in the fourth volution, 1:3.5 to 1:3.8 in the fifth volution, and 1:3.4 to 1:4.0 in mature forms. Axis of coiling essentially straight. The profile throughout growth is rather uniform, but there is a slight inflation near the poles in some mature specimens.

The thicknesses of the septa differ considerably in the different volutions and from the center to the poles in any one volution. This variation is due mainly to the variation in the thicknesses of the tectoria. The tectoria are rather dense; they thicken toward the base where they continue onto the "floors" of the chambers to form the upper tectorium of the spirotheca, and they become thinner near the upper portion of the septa where they continue at least partially onto the "roofs" of the chambers to form the lower tectorium of the spirotheca. These layers of tectoria decrease in thickness anteriorly in the last volution, and they increase in thickness

in passing laterally from the center to the poles where they, combined with the upper tectorium of the spirotheca, completely fill the chambers in all volutions except the last two. The diaphanotheca is about equal in thickness to the diaphanotheca of the spirotheca. The tectum is very thin and dense and is the downward extension to the base of the septa of the tectum of the spirotheca. The septa are unfluted and they are essentially straight throughout most of their length, but as they approach the poles they make sharp backward twists. There are about 13 septa in the second volution, 14 in the third volution, 15 in the fourth volution, 16 in the fifth volution, and 17 in the sixth volution.

The spirotheca or wall is composed of three complete layers and a fourth apparently incomplete layer. The upper tectorium is rather dense and is 12 microns thick in the fifth volution just beyond the limits of the chomata, and it increases to the entire thickness of the chambers in the polar regions where this layer, combined with the tectoria of the septa, completely fills the chambers in all volutions except those of the last one or two. The diaphanotheca is about 12 microns thick in the sixth volution. The lower tectorium seems to be only a partial covering that does not span the "roofs" of all the chambers, and it is formed by the continuation of the tectoria of the septa.

The proloculum is sub-spherical; it has a small flattened area around the aperture, and it is about 35 microns in diameter.

The cross section of the tunnel is elongate-elliptical. The tunnel does not increase in size uniformly during ontogenetic development but in mature individuals it is about one-half the height of the septa and about one-third as high as wide. The line of intersection of the tunnel with axial sections is not regular, but a determination of the tunnel angle made in the last volution gives 14 to 22 degrees. The chomata have a very steep slope toward the tunnel and a more gentle slope toward the poles; these ridges are very faint in the earlier stages of growth but they are about one-half the height of the chambers of the fifth and sixth volutions.

In general external appearances and form ratios of mature specimens *Wedekindellina dunbari* more closely resembles *W. euthysepta* (Henbest) than any other described species, but it differs from that form in that mature representatives of *W. euthysepta* are much larger than mature specimens of *W. dunbari,* and the form ratios of successive volutions in ontogenetic development of *W. dunbari* decrease gradually to maturity whereas the form ratios of

successive volutions of *W. euthysepta* decrease rapidly to the seventh volution and then increase to maturity. *W. dunbari* is relatively shorter and wider for corresponding volutions and has a smaller number of volutions than *W. euthysepta.*

Occurrence.—This species has been found in only a calcareous shale approximately 35 feet below the White Breast coal, in the west road-ditch, on the east line of Lucas County, Iowa, near the top of a north-sloping hill, east center SE¼ sec. 1, T. 73 N., R. 20 W. (pl. XX, figs. 3, 6, 15, 16, 20, 21); and in the same horizon in the south bank of a small west-flowing creek, 10 feet above the bed of the creek, 75 yards south of County road L, ½ mile west Lovilia, NE¼SW¼ sec. 10, T. 73 N., R. 18 W., Monroe County, Iowa.

Repository.—State University of Iowa, Catalogue Nos. 983-989 (cotypes); the figured specimens are Nos. 986-989.

WEDEKINDELLINA ELFINA Thompson, n. sp.

Plate XX, figures 8, 10, 11, 18, 19

Shell very minute, sub-fusiform, with sharply pointed poles; central portion slightly inflated; external furrows shallow; axis of coiling straight to broadly curved. Mature specimens are about 1.90 mm in length and 0.56 mm in width. The form ratio of mature specimens of 8 volutions is between 1:3.3 and 1:3.5. The form ratio for the third, fourth, and fifth volutions is 1:3.3, showing a uniform rate of growth throughout the length of the shell.

The septa are fairly straight except near the poles where they curve backward rather strongly. The two outer layers of tectoria are of about equal thickness; they thin toward the top of the septa and they thicken toward the base of the septa. The line of separation of the diaphanotheca of the septa and the posterior tectorium is somewhat indefinite, but the former layer can be distinguished from the latter by its slightly more nearly transparent nature and by its slightly more coarsely crystalline structure. The septal count for two typical specimens is 15 for the second volution, 16 for the third volution, 19 for the fourth volution, 21 for the fifth volution, and 22 for the sixth volution.

The proloculum is roughly a triaxial ellipsoid with the major axis parallel to the axis of coiling. The three axes, as measured from a number of sections, are respectively about 50, 40, and 30

microns in length. The inner three volutions are slightly more tightly coiled than the outer volutions.

The spirotheca or wall is relatively thick. The upper tectorium is about 6.0 microns in thickness in the fifth volution just beyond the limits of the chomata; it is rather dense, and it, combined with the lower parts of the tectoria of the septa, thickens very rapidly from the outer limits of the chomata so that it completely fills the chambers in the polar regions of all volutions except the first two or three. The diaphanotheca is of about the same density as the lower part of the upper tectorium, and it is about 8.0 microns in thickness in the sixth volution beyond the limits of the chomata. The lowest layer of the spirotheca, tectorium, is slightly more dense than the diaphanotheca; it is well developed over the tunnel and is about one-half as thick as the diaphanotheca, but beyond the limits of the chomata it is very thin near the septa and is exceedingly thin or even absent in the mid-length of the chambers.

The cross section of the tunnel is roughly elliptical in shape and it is about one-half as high as the septa and about one-half as high as long. The width of the tunnel varies considerably from one volution to the next and its intersection with an axial section is irregular; however, a determination made in the sixth volution gives a tunnel angle of 22 degrees. The floor of the tunnel is depressed and is covered by a part of the tectorium of the spirotheca of the preceding volution. The chomata are very low and broad.

Wedekindellina elfina is somewhat similar to *W. minuta* (Henbest) of the Tradewater formation of Illinois, but it differs from that species particularly in that its proloculum is smaller, mature specimens contain a larger number of volutions, and the ends of *W. elfina* are sharply pointed while those of *W. minuta* are bluntly pointed. It seems to me that Henbest has included two forms in *W. minuta,* but neither of these is conspecific with *W. elfina. W. elfina* differs from *W. uniformis* in that its central portion is inflated whereas *W. uniformis* has a uniform profile, and the axial fillings of *W. uniformis* are better developed in the early volutions than in *W. elfina.*

Occurrence.—Wedekindellina elfina has been found only in a calcareous shale beneath a thin limestone 35 feet below the White Breast coal, in the west road-ditch of the east line of Lucas County, Iowa, near the top of a north-sloping hill, east center SE¼ sec. 1,

T. 73 N., R. 20 W. (pl. XX, figs. 8, 10, 11, 18, 19); and in the same horizon in the south bank of a small west-flowing creek, 75 yards south County road L, 10 feet above the creek bed, ½ mile west Lovilia, Monroe County, Iowa, NE¼SW¼ sec. 10, T. 73 N., R. 18 W.

Repository.—State University of Iowa, Catalogue Nos. 962-968 (cotypes); the figured specimens are Nos. 965-968.

WEDEKINDELLINA UNIFORMIS Thompson, n. sp.
Plate XX, figures 4, 5, 14, 23

Shell minute, uniformly fusiform, with moderately sharply pointed poles; external furrows shallow. Mature specimens are about 2.00 mm in length and 0.70 mm in width. The rate of growth is very uniform throughout; the form ratio is 1:2.6 in the third volution, 1:2.9 in the fourth volution, and 1:3.0 in the fifth volution, and it remains constant in the outer portion of mature forms which consist of about 8½ volutions. The axis of coiling is straight.

The septa are very thick. They are composed of four layers. The outer two layers are each much thicker than the two inner layers combined. The combined thickness of these tectoria of the septa and the upper tectorium of the spirotheca completely fills the chamber in the polar regions in all volutions. The diaphanotheca is of about equal thickness to the diaphanotheca of the spirotheca. The diaphanotheca of the following chamber seems to extend about one-eighth the height of the septa down the anterior side of the tectum; this, however, may be considered as part of the spirotheca. The septa are unfluted and the external furrows are straight throughout the length of the specimen. There are about 13 septa in the second and third volutions, 15 in the fourth volution, 17 in the fifth volution, 18 in the sixth volution, and 22 in the seventh volution.

The spirotheca or wall is very thick laterally from the tunnel and is made up of four layers. The upper and lower tectoria are rather dense and are the continuations of the tectoria of the septa. The upper tectorium is about 10 microns in thickness in the line of the tunnel of the sixth volution and thickens very rapidly until it completely fills the chambers in the polar regions; the lower tectorium is extremely thin and only appears as a slightly darker line at the base of the diaphanotheca. The diaphanotheca is about 8 microns thick in the sixth volution and 12 microns thick in the

last chamber of specimens of seven and one-half volutions. In some specimens the lower part of the upper tectorium of the spirotheca is about equal in density to the diaphanotheca, and the tectum appears as a dark line near the center of a thick homogeneous layer.

The proloculum is essentially spherical and measures 35 to 40 microns in diameter. The first four volutions are tightly coiled and the remaining volutions are more loosely coiled. The axis of the first volution in all specimens is at an angle to the axis of the remaining outer volutions and axial sections may appear as a sagittal section for the inner volution (see fig. 5, pl. XX).

The cross section of the tunnel is sub-elliptical and is about one-half as high as wide and a little more than one-half the height of the antetheca. Each side of the tunnel is bordered, except in the last two volutions, by a very asymmetrical ridge, choma, that has a very steep slope next to the tunnel and a very gentle downward slope away from the tunnel. The floor of the tunnel is underlain by the upper layer, tectorium, of the spirotheca. The intersection of the line of the tunnel with axial sections is relatively straight for the genus, and determinations of the tunnel angle give 15 to 20 degrees.

Wedekindellina uniformis seems to be more closely similar to *W. elfina* than to any other described species. *W. uniformis* can be distinguished from that species by its larger form ratio, more uniform profile, thicknesses of the layers of the spirotheca, and the development of its early volutions. *W. uniformis* may be distinguished from *W. minuta* (Henbest) by its larger form ratio, its more sharply pointed poles, and its more numerous volutions; also, the general shape of the shell of these two species is different.

Occurrence.—This species occurs sparingly in a calcareous shale 35 feet below the White Breast coal in the west road-ditch, on the east line of Lucas County, Iowa, near the top of a north-sloping hill, east center SE¼ sec. 1, T. 73 N., R. 20 W. (pl. XX, figs. 4, 5, 14, 23); and very sparingly in the same horizon on the south bank of a small west-flowing creek, 10 feet above the bed of the creek, 75 yards south of County road L, ½ mile west of Lovilia, Monroe County, Iowa, NE¼SW¼ sec. 10, T. 73 N., R. 18 W.

Repository.—State University of Iowa, Catalogue Nos. 969-974 (cotypes); the figured specimens are Nos. 972-974.

Genus FUSULINELLA Möller

The genus *Fusulinella* was established by Möller[13] in 1877, but it was a year later[14] before any species were referred by name to it; at this later time Möller referred four species to the genus, but he did not designate a genotype. In 1906 Douvillé[15] designated *Fusulinella bocki,* the first species described under the name *Fusulinella,* as the genotype, and it is clear from Möller's original generic diagnosis that this is the type of shell for which he founded the genus. One of the remaining three species referred to this genus by Möller in 1878, *F. sphaerica,* has subsequently been made the type of the genus *Staffella* by Ozawa.[16] This latter genus includes at least one of the two remaining species described under *Fusulinella* by Möller in 1878, *Melonia* (*Borelis*) *sphaeroidea* Ehrenberg; the other one, *F. bradyi* Möller, has been referred by Galloway and Harlton to *Orobias.*

In the Schellwien-Staff monographs, and some others, the name *Fusulinella* is used to refer to forms which are congeneric with *Staffella sphaerica* and quite different from *Fusulinella bocki.* Other paleontologists have used this generic name to designate forms now known to be congeneric with *Fusulina cylindrica,* the type of the genus *Fusulina.* The limits of the genus *Fusulinella* have become clearer since the true nature of *Fusulina cylindrica* Fischer-de-Waldheim, the type of *Fusulina,* has been described by Lee[17] and by Dunbar and Henbest.[18]

The genus *Neofusulinella* was proposed by Deprat[19] in 1912 for an unnamed species of Fusulinidae "dans les calcaires rapportés de Bam-Na-Mat (entre Sam-Neua et Luang-Prabang), par M.

13 Möller, V. von, Ueber Fusulinen und ähnliche Foraminiferen-Formen des russischen Kohlenkalkes: *Neues Jahrb. Min. Geol. und Pal.,* Jahrg. 1877, pp. 144-146.

14 Möller, V. von, Die Spiral-Gewundenen Foraminiferen des russischen Kohlenkalks: *Mém. Acad. Imp. Sci. St. Pétersbourg,* ser. 7, vol. 25, no. 9, 1878.

15 Douvillé H., Les calcaires a Fusulines de l'Indo-Chine: *Bull. Soc. Géol. France,* ser. 4, vol. 6, p. 584, 1906.

16 Ozawa, Y., On the Classification of Fusulinidae: *Jour. Coll. Sci., Imp. Univ. Tokyo,* vol. 45, art. 4, p. 24, 1925.

17 Lee, J. S., Fusulinidae of North China: *Palaeontologia Sinica,* ser. B, vol. 4, fasc. 1, pp. 32-35, 1927.

18 Dunbar, C. O., and Henbest, L. G., The fusulinid genera *Fusulina, Fusulinella* and *Wedekindella*: *Am. Jour. Sci.,* ser. 5, vol. 20, pp. 357-364, 1930.

19 Deprat, J., Sur deux genres nouveaux de Fusulinidés de l'Asie orientale, intéressants au point de vue phylogénique: *Comptes R. Acad. Sci., Paris,* vol. 154, pp. 1548-1550, 1912.

Mansuy''; in this same publication Deprat stated (page 1550): ''En effet il [the fusulinid species for which he was establishing the new genus] se trouve dans les calcaires permiens à *Doliolina lepida*''. The following year Deprat[20] described the species for which he had originally founded the genus and two other new species which he had encountered since he had established the genus. This was the first time that any named species were referred to this genus. It is clear that Deprat based his genus on a species from the Permian of Bam-na-mat between Sam-neua and Luang-prabang (Laos) that was collected by M. Mansuy. The three species first referred by name to this genus, *Neofusulinella,* in 1913 by Deprat were described in the following order: first, *N. praecursor* Deprat from the base of the Moscovian of Cammon (Laos), second, *N. lantenoisi* Deprat from the Permian of Ban-na-mat (Laos) which was collected by M. Mansuy, and third, *N. schwagerinoides* Deprat from the Moscovian of Cammon. Deprat's original diagnosis of the genus was based on a single species for which he later coined the name *N. lantenoisi,* and it clearly is the genotype of *Neofusulinella.* Galloway and Ryniker[21] have stated that the type of *Neofusulinella* is *N. praecursor* Deprat, the first species to be referrd by name to the genus. It is clear that *N. praecursor* and *N. schwagerinoides* were not included in the original description of the genus, and that *N. lantenoisi* was the only species involved. Therefore, in accordance with Article 30, I, (c), and Opinion 46 of the International Rules of Zoological Nomenclature, *N. lantenoisi* Deprat is the gentoype of *Neofusulinella.* In Deprat's fourth memoir on the family Fusulinidae (*Mém. Service Géol. Indochine,* vol. 4, fasc. 1, 1915) he described three additional species, *N. elongata, N. giraudi* and *N. minima,* from the Permian limestone of Cammon (Laos) under the name *Neofusulinella.* One of these last three species described by Deprat, *N. giraudi,* has been made the type of a new genus *Depratella* by Ozawa.[22] Ozawa stated that his genus can be distinguished from other genera of Fusulinidae by its very small size and *Endothyra*-like asymmetrical early volu-

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[20] Deprat, J., Les Fusulinidés des Calcaires Carbonifériens et Permiens du Tonkin, du Laos et du Nord-Annam: *Mém. Service Géol. Indochine,* vol. 2, fasc. 1, pp. 40-44, 1913.

[21] Galloway, J. J., and Ryniker, C., Foraminifera from the Atoka formation of Oklahoma: *Oklahoma Geol. Survey,* Circ. 21, pp. 22-23, 1930.

[22] Ozawa, Y., A new genus, *Depratella,* and its relation to *Endothyra*: *Contr. Cushman Lab. Foram. Research,* vol. 4, pt. 1, no. 55, pp. 9-10, 1928.

tions. It has been stated by Ozawa that the first three species referred to the genus *Neofusulinella* by Deprat have heavy depositional layers [tectoria] on the walls and septa and that they belong to the genus *Fusulinella,* and that this genus *Depratella* Ozawa lacked these deposition layers; this is probably true for *N. praecursor* and *N. schwagerinoides* of the Moscovian, but an examination of Deprat's illustrations and descriptions of *N. lantenoisi,* the genotype of *Neofusulinella,* and *N. giraudi,* the genotype of *Depratella,* leave no doubt that their wall structures as well as other internal features are not materially different, and they are both from the same general stratigraphic horizon. It seems then that we must consider *Depratella* a synonym of *Neofusulinella.*

The species *N. praecursor* and *N. schwagerinoides* are more closely related to the genotype of *Fusulinella* than to any other genotype. The form referred by Deprat to the genus *Fusulinella* in 1913, *F. quadrata,* is clearly more closely related to *Staffella sphaerica,* the genotype of *Staffella,* than to any other recognized genotype. The generic relationships of *N. lantenoisi,* the genotype of *Neofusulinella,* to *Fusulinella bocki,* the genotype of *Fusulinella,* however, are not so clear. Deprat's illustrations of this species (Deprat's pl. 7, figs. 23-25) do not lend themselves to a clear understanding of the internal structures, but they suggest a more highly developed form which lacks the thick tectorium found in *Fusulinella bocki.* This line of evidence suggests very strongly that *N. lantenoisi* (and therefore *N. giraudi*) are congeneric with *Schubertella transitoria* Staff and Wedekind, the genotype of *Schubertella* Staff and Wedekind, which also is not well known.

The illustrations and description of the genotype of *Yangchienia* Lee,[23] *Y. iniqua* Lee of the Chihsia limestone (lower Permian) near Nanking, suggest that it is closely related to *N. lantenoisi* and it may be congeneric with that species. However, the spirotheca of *N. lantenoisi* appears to be thicker than that of *Y. iniqua* due largely to a thicker diaphanotheca in *N. lantenoisi,* also the chomata of these two species are slightly different. The early volutions of *N. lantenoisi* have not been well illustrated but they are probably like those of *Y. iniqua.* The general stratigraphic horizon of these two genotypes is about the same; and the only major difference between

[23] This genus was proposed by Lee in 1933 (Lee, J. S., Taxonomic criteria of Fusulinidae with notes on seven new Permian genera: *Mem. Nat. Research Inst. Geol.,* no. 14, p. 14) and with only the genotype referred to it.

the two species appears to be that *Y. iniqua* has a larger chomata and thinner diaphanotheca than *N. lantenoisi.*

From a study of the illustrations and descriptions of the genotype, the descriptions and illustrations of congeneric species, and the specimens available for study, I have drawn up the following generic diagnosis of *Fusulinella*: Shell small, fusiform and short, with an essentially straight axis of coiling. Mature specimens are of ten or less volutions, have a relatively large form ratio, and usually do not exceed 3 mm in length. The septa are composed of an anterior and posterior tectorium, a tectum, and a diaphanotheca. The lower part of the septa are essentially straight to broadly fluted in the polar regions, and are unfluted in the midportion of the shell. The spirotheca is composed of a thick upper tectorium, a tectum, a diaphanotheca, and a relatively thin lower tectorium. The upper tectorium thins slightly poleward from the center of the shell. The tunnel is bordered on either side by an asymmetrical ridge, choma, which has a gentle slope poleward and a relatively steep slope on the tunnel-side.

The name *Fusulinella* has been used to designate a rather large number of American species that are now known to represent at least two genera, *Fusulina* s. s. and *Wedekindellina,* but up to the present it has not been used to designate any American species that are congeneric with *Fusulinella bocki,* the genotype of *Fusulinella.* The following American species seem to be more closely related to *Fusulinella bocki* than to any other recognized genotype and should therefore be referred to the genus *Fusulinella*: *Fusiella primaeva* Skinner and *Fusulina llanoensis* Thomas of the Marble Falls formation (Bend) of Texas, and *Fusulinella iowensis* Thompson of the lower part of the Cherokee of Iowa, described below. It seems probable that *Schubertella transitoria* Galloway and Ryniker (not *S. transitoria* Staff and Wedekind) of the Atoka formation of Oklahoma and *Schubertella gallowayi* Skinner of the Cherokee of Oklahoma are more closely related to *F. bocki* than any other proposed genotype. As can be seen from the above list the genus *Fusulinella* is rather widespread in North America, and it includes some of the oldest known American fusulinids. In America the genus is not known to occur in beds older than the Marble Falls formation nor in beds younger than the middle of the Cherokee, and elsewhere in the world it is generally limited to the Lower Pennsylvanian. How-

ever, in 1925 Ozawa[23a] described a form, *F. itoi,* from Japan and stated that it was Upper Permian in age. This species is very similar to *F. bocki* of the Lower Pennsylvanian of Russia and its age needs verification.

Since the true nature of *Fusulina cylindrica* has become clear, some doubt has been expressed as to the validity of the genus *Fusulinella,* and it has been placed in synonymy with *Fusulina* by some paleontologists. In the forms here referred to *Fusulinella* the septa are only very weakly fluted in the polar regions whereas the septa are fluted throughout the length of the shell in typical representatives of *Fusulina* s. s. The chomata of typical representatives of *Fusulinella* are much more strongly developed than are those of *Fusulina.* The spirotheca of representatives of *Fusulina* are usually much thinner, and the shells are usually more elongate. The characters of these two groups of species seem to me to be so very distinctive that there is little reason to believe that all are congeneric, and I am therefore recognizing the validity of both *Fusulina* and *Fusulinella.*

The genus *Wedekindellina* differs from *Fusulinella* particularly in that its representatives are more slender and smaller, they have different developments of the tectoria that fill the chambers in the polar regions, and their septa are essentially unfluted. The relationship of *Fusulinella* to the genus *Schubertella,* as well as to *Neofusulinella, Depratella,* and *Yangchienia,* is not so clearly known, but these forms seem to differ from *Fusulinella* in that their spirotheca does not contain the layers of tectoria which are invariably present in *Fusulinella*; also their early volutions are different from those of *Fusulinella.* The stratigraphic positions of the species on which these four genera were based are quite different from that of known representatives of *Fusulinella,* and it is probable that other generic distinctions can be pointed out after further studies have been made. In general shape *Fusulinella* resembles *Fusiella* somewhat closely, but representatives of these two genera may be readily distinguished for in representatives of *Fusulinella* there are four distinct layers in the spirotheca whereas only three layers can be distinguished in representatives of *Fusiella.* The chomata are very faint in *Fusiella* but the chomata

[23a] Ozawa, Y., Paleontological and stratigraphical studies on the Permo-Carboniferous limestone of Nagato: *Jour. Coll. Sci, Imp. Univ. Tokyo,* vol. 45, art. 6, p. 19, pl. 3, figs. 6, 8, 1925.

of *Fusulinella* are well developed. Also, representatives of *Fusiella* are more elongate and smaller than are those of *Fusulinella,* and the inner volutions of the two genera are quite different.

FUSULINELLA IOWENSIS Thompson, n. sp.

Plate XX, figures 28-30

Shell small, short, obese, uniformly fusiform, and with bluntly pointed poles. The axis of coiling is straight and the external furrows are shallow. Mature specimens consist of 9 to 11 volutions and are about 2.8 mm in length and 2.0 mm in width. The form ratio of mature forms is about 1:1.4, and it is 1:1.5 in the third, fourth, and fifth volutions, and 1:1.4 in the remaining outer volutions.

The traces of the external furrows are essentially straight throughout the length of the shell. The lower portions of the septa are broadly fluted in the extreme polar regions of the inner volutions and they are essentially straight near the tunnel, but the fluting seems to extend nearer the tunnel in the ninth and tenth volutions. The septa are relatively thick and are composed of an anterior and posterior tectorium, a tectum, and a diaphanotheca. The diaphanotheca and tectum are downward continuations of the two inner layers of the spirotheca, and the diaphanotheca is about 8 microns thick in the sixth volution near the tunnel and 11.2 microns thick in the eighth volution near the tunnel. The tectoria are very thick near the base of the septa where they continue onto the "floors" of the chambers to form the very thick upper tectorium of the spirotheca, but they thin rapidly upward to the top of the septa where they continue onto the "roofs" of the chambers to form the thin lower tectorium of the spirotheca. The septal count gives 17 for the second volution, 22 for the third volution, 27 for the fourth volution, 29 for the fifth volution, and 33 for the sixth volution. The antetheca and hence septa of this species extend forward so as to join the spirotheca of the preceding volution at an angle of about 60 degrees.

The proloculum is sub-spherical to irregular in shape and it is 45 to 70 microns in diameter. The inner one and one-half volutions are more tightly coiled than are the outer volutions.

The spirotheca is relatively thick, the thickness being due largely to a thick upper tectorium. The upper tectorium is about 19 microns thick in the center of the tunnel of the sixth volution and 30 to 40 microns thick midway between the tunnel and the pole of

the sixth volution. The diaphanotheca is very clear and is about 11.0 microns thick in the sixth volution and 18 microns thick in the ninth volution.

The cross-section of the tunnel is elliptical and the intersection of the tunnel with axial sections is essentially straight. The tunnel is about one-third the height of the chambers in the eighth volution and about one-half as high as wide. The tunnel angle is very small and measures 12 to 14 degrees. The tunnel is bordered on either side by an asymmetrical ridge, choma, which has a very steep slope on the tunnel-side and a more gentle slope poleward. The chomata are two-thirds to three-fourths the height of the chambers and their crests are broadly rounded. The septa in the line of the chomata are greatly thickened and some of the chambers are completely filled along this zone. The poleward limits of the chomata are rather difficult to locate but they seem to be about one-third the distance between the tunnel and the poles.

The representatives of this very interesting species are the oldest fusulinids known from Iowa. *Fusulinella iowensis* is so distinct from all other described American species that detailed comparisons are hardly necessary. The similarity between *F. iowensis, F. bocki* Möller, and *F. biconica* (Hayasaka) is remarkable. These forms are specifically distinct, but they are certainly closely related.

Occurrence.—This species has been found rather abundantly in a limestone member of the lower part of the Cherokee, in a small creek about 200 yards south of the bridge over Cedar Creek, NW¼ sec. 33, T. 71 N., R. 9 W., Jefferson County, Iowa. The fusulinid-bearing limestone at this locality immediately overlies the second coal above the Mississippian limestone; this coal is about 4 feet thick and here it is located stratigraphically about 20 feet above the Mississippian limestone and about 90 feet below the White Breast coal. Poorly preserved specimens have been found at the same horizon on the east bank of Soap Creek near the center of the SE¼ sec. 6, T. 70 N., R. 12 W., ½ mile south Laddsdale, Davis County, Iowa. This limestone forms the cap for the thick coal that is mined by drifts slightly above the level of the highway near the abandoned town of Laddsdale. All the figured specimens came from the Jefferson County locality.

Repository.—State University of Iowa, Catalogue Nos. 996-1000 (cotypes); the figured specimens are Nos. 996-997, and 999.

Genus FUSULINA Fischer-de-Waldheim

In 1829 Fischer-de-Waldheim[24] established the genus *Fusulina* for two species from the Upper Carboniferous (Lower Pennsylvanian equivalent) of Miatschkowo, Russia, which he[25] described eight years later as *Fusulina cylindrica* and *F. depressa.* This generic term has been applied to a great variety of fusulinids, but within the last few years the scope of the genus *Fusulina* has been greatly restricted and at present it includes only species which are very closely similar to *F. cylindrica,* the genotype. In America, representatives of this genus in a restricted sense are known to occur only in strata ranging in age from the lower part of the Cherokee to the top of the Des Moines.

In the original description of *F. cylindrica,* the characters which are today used to differentiate fusulinid species and genera are not clearly illustrated or described, but topotypes of this species have subsequently been illustrated and described by a number of paleontologists, among whom may be mentioned Brady[26], Möller[27], Schellwien-Staff[28], Lee[29], and Dunbar and Henbest[30]. Möller interpreted the spirotheca of *F. cylindrica* as being like that of Upper Pennsylvanian and Lower Permian forms, that is, composed of a tectum and a keriotheca with aveoli. Subsequent workers followed Möller in his interpretation of the spirotheca of *F. cylindrica,* and, as the septa of *F. cylindrica* are definitely fluted throughout the length of the shell, they referred to *Fusulina* forms which have this type of septa fluting and spirotheca; these are now placed in the genera *Leeina. Pseudofusulina, Parafusulina,* and *Polydiexodina.*

24 Fischer-de-Waldheim, G., Les Céphalopodes fossiles de Moscou et de ses environs: *Bull. Soc. Imp. Natur. Moscou,* vol. 1, p. 330, 1829.

25 Fischer-de-Waldheim, G., Oryctographie du Gouvernement de Moscou 1830-37, pp. 126-127, 1837.

26 Brady, H. B., Notes on a group of Russian fusulinae: *Ann. Mag. Nat. Hist.,* ser. 4, vol. 18, pp. 415-416, pl. 18, figs. 1-4, 1876.

27 Möller, V. von, Die spiral-gewundenen Foraminiferen des russischen Kohlenkalks: *Mém. Acad. Imp. Sci. St. Pétersbourg,* ser. 7, vol. 25, no. 9, pp. 51-54, pl. 1, figs. 2a-2h, pl. 7, figs. 1a-1d, 1878.

28 Schellwien, E., by Staff, H. von, Monographie der Fusulinen, Teil I, Die Fusulinen des russisch-arktischen Meeresgebietes: *Palaeontographica,* vol. 55, pp. 161-163, pl. 13, figs. 1-11 (not figs. 12-13), 1908.

29 Lee, J. S., Fusulinidae of North China: *Palaeontologia Sinica,* ser. B., vol. 4, fasc. 1, pp. 32-35, pl. 4, fig. 8 (not pl. 1, fig. 3, pl. 4, figs. 1-7), 1927.

30 Dunbar, C. O., and Henbest, L. G., The fusulinid genera *Fusulina, Fusulinella* and *Wedekindella*: *Amer. Jour. Sci.,* ser. 5, vol. 20, pp. 357-364, 1930.

When Lee studied topotypes of *Fusulina cylindrica* in 1927, he discovered that in this species the spirotheca has a structure like that of *Fusulinella,* as first described by Möller in 1877, and quite different from the higher Pennsylvanian and Permian forms. In 1930 Dunbar and Henbest also described the spirotheca of *F cylindrica* as being like that of *Fusulinella,* and they restricted the name *Fusulina* to Lower Pennsylvanian forms like those described below.

In 1909 Staff[31] proposed the name *Girtyina* for a subgenus of *Fusulina* and stated that the subgenotype is *G. ventricosa* Meek. Previously, on the same page, he spoke of his subgenus as being represented by *Fusulina (Girtyina) ventricosa* in Schellwien's manuscript; this manuscript was published by Staff in 1912, and the form described in it as *Girtyina ventricosa*[32] is not at all like the type specimens of *Fusulina ventricosa* Meek and Hayden which represent the genus *Triticites,* but is more nearly like *F. cylindrica* than any other genotype. *G. ventricosa* of Staff (not of Meek and Hayden) has subsequently been named *Fusulinella girtyi* by Dunbar and Condra. Opinion 65 of the International Rules of Zoological Nomenclature states that if an author designates a certain species as genotype it is to be assumed that his determination of the species is correct. If this opinion is to be followed strictly, *Girtyina* is a synonym of *Triticites,* which was established in 1904. However, it seems clear that Staff based his genus *Girtyina* on specimens from Illinois sent to Europe by Meek, who erroneously labeled them *Fusulina ventricosa*; these are now known as *Fusulina girtyi* (Dunbar and Condra). *F. girtyi* has been made the type of a genus *Beedeina* by Galloway[33]. After a detailed study of the illustrations and descriptions of the types of *F. girtyi* and conspecific specimens from Iowa, I am of the opinion that this species is so similar to *F. cylindrica,* the genotype of *Fusulina,* that the two should be regarded as congeneric, and I therefore am suppressing *Beedeina* as a synonym of *Fusulina.*

The following North American species are more nearly similar and presumably more closely related to *Fusulina cylindrica,* the genotype of *Fusulina,* than any other recognized genotype and

[31] Staff, H. von, Beiträge zur Kenntnis der Fusuliniden: *Neu. Jahrb. Min. Geol. Pal.,* Beilage-B. 27, p. 490, 1909.

[32] Staff, H. von, Monographie der Fusulinen, Teil III, Die Fusulinen (Schellwienien) Nordamerikas: *Palaeontographica,* vol. 59, pp. 164-165, pl. 18, figs. 2, 5, 7, 1912.

[33] Galloway, J. J., A manual of Foraminifera: p. 401, 1933.

should therefore be referred to the genus *Fusulina*: *Fusulina inconspicua* Girty of the Wewoka of Oklahoma; *Girtyina haworthi* Beede of the lower Fort Scott limestone of Kansas; *Fusulinella girtyi* Dunbar and Condra of the Carbondale formation of Illinois; *Fusulina tregoensis* [= *F. meeki tregoensis*] Roth and Skinner of the Cherokee of Kansas; *F. minutissima* R. and S. and *F. hartvillensis* R. and S. of the Hartville limestone of Wyoming; *F. distenta* R. and S. and *F. rockymontana* R. and S. of the McCoy formation of Colorado; *F. leei* Skinner of the Cherokee of Oklahoma; *F. similis* [= *F. meeki similis*] Galloway and White of the Millsaps formation of Texas; and the forms from the Des Moines series of Iowa described below as *Fusulina? problematica*, *F. pumila*, *F. euryteines*, *F. kayi*, *F. lucasensis*, *F. stookeyi*, *F. megista*, *F. mysticensis*, and *F. eximia*. From the above list it can be seen that the genus *Fusulina* is widespread geographically in North America, and it is known to occur in Europe and Asia and probably in South America. However, its stratigraphic range is limited and it is not known to occur in beds older than the lower part of the Cherokee nor in beds younger than the top of the Des Moines series.

From a study of the descriptions and illustrations of the genotype and conspecific species and all of the numerous specimens available, I have drawn up the following generic diagnosis of the genus *Fusulina*: Shell fusiform to sub-cylindrical, more or less elongate; mature forms vary from about 2.5 to 10 mm in length and from about 1 to 3.5 mm in width. Axis of coiling straight to irregular. External furrows shallow. The spirotheca is composed of an upper tectorium which thins slightly poleward, a tectum, a thin diaphanotheca, and a thin lower tectorium. In some of the more highly developed representatives of the genus the lower tectorium is exceedingly thin or even absent in the mid-length of the chambers beyond the limits of the chomata. The septa are composed of an anterior and posterior tectorium, a tectum, and a diaphanotheca; the tectum and the diaphanotheca are the downward continuations of the tectum and the diaphanotheca of the spirotheca of the preceding chamber. The septa are fluted throughout the length of the shell and the fluting is typically more intense and higher in the polar regions than near the tunnel. The inner volutions are typically symmetrical and fusiform. The tunnel is low and is bordered on either side by deposits, chomata, that form distinct ridges in the inner volutions, but are more or less irregular in the outer volutions.

Representatives of the genus *Fusulina* can be distinguished from those of *Triticites* by the fact that in *Fusulina* the septa are fluted throughout their entire length, whereas in *Triticites* they are essentially straight across the mid-portion of the shell. The spirotheca in *Fusulina* is composed of four layers whereas in *Triticites* it is composed of only two layers, a tectum and a keriotheca—the keriotheca shows an aveoli structure; also the stratigraphic range of the two genera is different. Representatives of *Fusulina* can be distinguished from those of *Fusulinella* by their highly fluted septa throughout the length of the shell and by the less highly developed chomata in *Fusulina*. The spirotheca is typically thinner and the shell is typically more elongate in *Fusulina* than in *Fusulinella*. In *Pseudofusulina* and *Leeina* the structure of the spirotheca and the septa differs from that of *Fusulina*.

The genus *Fusulina* does not constitute as compact a group of species as does *Wedekindellina*, *Fusulinella* and some other genera of primitive fusulinids, for the shape of the shells as well as the intensity of the septal fluting is quite variable in different species. This difference however is more apparent than real for a critical examination of such apparently widely different species as *F. girtyi*, *F. mysticensis*, and *F. kayi* brings out the fact that they differ only in degree and not in structure.

Fusulina leei Skinner

Plate XXI, figures 3, 7, 10, 18

Fusulina leei Skinner, *1931,* Jour. Pal., vol. 5, pp. 257-258, pl. 30, figs. 4, 6.

Shell minute, sub-cylindrical to fusiform, elongate, with bluntly pointed poles, with irregular axis of coiling, and with very faint external furrows. Form ratio of mature specimens is about 1:3.3, and the form ratio is about 1:2.7 in the third volution, 1:2.9 in the fourth volution, 1:3.1 in the fifth volution, and 1:3.3 in the sixth volution. Mature specimens consist of 6½ to 7 volutions, and they are about 4.25 mm in length and 1.25 mm in width. The profile of the mid-portion of the shell is uniform in all volutions, but the extreme polar regions of the last 3 volutions are slightly inflated.

The septa are rather narrowly fluted throughout the length of the shell. The fluting divides the chambers into chamberlets that are shaped like inverted and truncated cones and are separated by fusions of the septa that reach about four-fifths the height of the

chambers. The external furrows are relatively straight across the median portion of the shell, but they make broad backward twists in the regions of the poles. The septa are relatively thin and are composed of four distinct layers. The anterior and posterior tectoria are relatively thin. The diaphanotheca is about 7.0 microns thick in the sixth volution about two-thirds the distance from the tunnel to the poles. Where the septa are fused up to near the top of the chambers by points of contact of the fluting, only the diaphanotheca of the posterior chamber seems to be fully developed. The diaphanotheca is recognizable in the outer five volutions and is completely developed in the antetheca of the last chamber. The septal count of two typical specimens is 12 for the first volution, 17 for the second volution, 20 for the third volution, 22 for the fourth volution, 25 for the fifth volution, and 28 for the sixth volution.

The proloculum is spherical, and it is about 85 microns in diameter, and its wall is about 14.5 microns thick. The development of the shell of this species is divisible into an early stage (a "juvenarium") during which the inner three volutions are very tightly coiled, and a later stage during which the chambers of the outer volutions were more highly vaulted.

The spirotheca or wall is relatively thin. The lower tectorium is slightly thicker over the roof of the tunnel than in the region of the poles. The different layers with their respective thicknesses in the sixth volution, about one-half the distance from the center of the tunnel to the poles, are: upper tectorium 7.8 microns, diaphanotheca 7.0 microns, and lower tectorium 11.7 microns—the tectum is so thin that it cannot be measured accurately. The lower tectorium is slightly more dense than the upper tectorium and the diaphanotheca is slightly less dense and more coarsely crystalline than the upper tectorium.

The intersection of the line of the tunnel with axial sections is slightly irregular, and the tunnel angle is about 32 degrees. Both sides of the tunnel are bordered by the chomata which have a broadly rounded upper surface and are about two-thirds as high as the chambers and about one-half as high as broad. The floor of the tunnel is covered by the upper tectorium of the spirotheca which is slightly thicker near the center of the tunnel than near its borders.

The specimens from Iowa which I am referring to ***Fusulina leei*** present some slight differences from the figured holotype (Skinner's pl. 3, fig. 4), but they seem to agree fairly well with the

original description. The Iowa specimens are smaller in all dimensions and the thicknesses of the layers of the spirotheca are not exactly the same as those given by Skinner.

Fusulina leei resembles rather closely *F. kayi,* with which it is found associated, but it can be distinguished from that species particularly by its smaller form ratio, its larger tunnel angle, its more extended polar regions, and its more bluntly pointed poles; also, the fluting of this species is broader than that of *F. kayi.*

Occurrence.—The type specimens of this species came from the Cherokee of Oklahoma, immediately above the Bluejacket sandstone. In Iowa representatives of this species have been obtained from only a calcareous shale 1½ feet below a thin limestone, 35 feet below the White Breast coal, in the west road-ditch, on the east line of Lucas County, Iowa, SE¼ sec. 1, T. 73 N., R. 20 W. (pl. XXI, figs. 3, 7, 10, 18); and from the same horizon in the south bank of a small west-flowing creek, 10 feet above the bed of the creek, 75 yards south of County road L, ½ mile west of Lovilia, SW¼ sec. 10, T. 73 N., R. 18 W., Monroe County, Iowa.

Repository.—State University of Iowa, Catalogue Nos. 854-860 (plesiotypes); the figured specimens are Nos. 857-860.

FUSULINA KAYI Thompson, n. sp.

Plate XXI, figures 1, 2, 4, 5, 8, 12-15, 19, 20

Shell small, uniformly fusiform, slightly elongate, with rather sharply pointed poles, with straight axis of coiling, and with shallow external furrows. Mature specimens of 7 volutions are 3.70 to 4.0 mm in length and about 1.3 mm in width. The rate of increase in size is rather uniform throughout the length of the shell but there is a uniform decrease of form ratio—in the third volution the form ratio is 1:1.9, in the fourth volution 1:2.2, in the fifth volution 1:2.4, in the sixth volution 1:2.6, and in mature specimens 1:2.8.

The septa are relatively thin and are composed of four layers. The two outer layers are thicker in the lower part of the septa where they fuse adjacent septa for about two-thirds the height of the chambers at the points of approach caused by the fluting. The posterior portion of the anterior tectorium is somewhat lighter than the remaining portion but it does not seem to join structurally with the diaphanotheca of the following chamber. The external furrows

have an irregular course across the mid-portion of the shell but they are somewhat sinuous in the region of the poles. The septa are very highly fluted throughout the length of the shell and the fluting extends to the top of the septa; however, it is less pronounced in the upper one-third of the chamber. Tangential sections show the flutings to form short elliptical openings or chamberlets; these are located in the lower portion of the chambers and they are about two-thirds as high as the chambers. The septal count for the earlier volutions of the shell is about 17 in the second volution, 19 in the third volution, 24 in the fourth volution, and 28 in the fifth volution. In some specimens the septal count varies as much as four in the fourth volution and three in the fifth volution.

The proloculum is sub-spherical to spherical and has a diameter of 80 to 100 microns. The ontogenetic development of individuals is divisable into an early stage (a ''juvenarium'') during which the inner two and one-half volutions are tightly coiled and a later stage during which the outer volutions are less tightly coiled.

The spirotheca or wall is relatively thick. The upper tectorium is about 6.0 microns thick in the sixth volution and is composed of rather dense material which is slightly less dense near its lower surface. The diaphanotheca measures 5.9 microns in the sixth volution. The lower tectorium is about 11.7 microns thick over the tunnel in the sixth volution but it thins rapidly toward the poles and is absent in the last volution. The upper tectorium is present on the floors of all chambers but it is not found on the spirotheca of the last volution. The difference in density between the diaphanotheca and the lower part of the upper tectorium is very slight and the line of division would be very difficult to locate if it were not for the presence of the tectum.

The tunnel is rather low and broad and it is about one-third as high as the chamber and about one-fourth as high as wide. The average tunnel angle is about 22 degrees. The floor of the tunnel is covered by a thick layer of tectorium, and either side of the tunnel is bordered by a very high and broadly rounded, more or less symmetrical ridge, the choma, which, in the fifth and sixth volution, is about two-thirds as high as the chambers and is about as broad at the top as it is high—it is only slightly developed in the outer volution.

Two groups of specimens are included under this species which are somewhat doubtfully conspecific but which present certain sim-

ilarities. The above description is based almost entirely on the first group of these specimens which is represented by figures 2, 5, 8, 14, and 20 on plate XXI—they differ from the second group of specimens represented by figures 1, 4, 12, 13, 15, and 19 on plate XXI particularly in that the septa are more narrowly fluted, the shells are larger, and the form ratios for corresponding volutions are larger. The second group of specimens included under this species resembles *F. inconspicua* Girty in general measurements and outline of the shell. However, the fluting of the septa of *F. inconspicua* is much broader than in these specimens and the tunnel angle is much larger—the tunnel angle of *F. inconspicua* is over 40 degrees.

Among the collections of fusulinids which I am studying from outside the confines of Iowa there is an excellent collection from Girty's type locality of *F. inconspicua* of the Wewoka formation of Oklahoma that was very generously sent me by Mr. R. V. Hollingsworth of the University of Chicago. These topotypes of *F. inconspicua* agree in every detail with Girty's figured cotypes, and they show clearly that *F. inconspicua* is not conspecific with any specimens so far found in Iowa.

Fusulina kayi differs from *F. leei* particularly in that it is shorter, it has a smaller tunnel angle, a larger form ratio, its poles are more sharply pointed, and its septa are more narrowly fluted.

This species is named in honor of Dean George F. Kay, Director of the Iowa Geological Survey, who continually encouraged the writer in his work and who made possible the field work necessary for the preparation of this report.

Occurrence.—This species is known from only one horizon, this is, from a calcareous shale 1½ feet below a thin limestone, 35 feet below the White Breast coal. My collections contain large numbers of specimens from the west road-ditch on the east line of Lucas County, Iowa, near the top of a north-sloping hill, east side SE¼ sec. 1, T. 73 N., R. 20 W. (all figured specimens); and from the south bank of a small west-flowing creek, 10 feet above the bed of the creek, 75 yards south of County road L, ½ mile west of Lovilia, SW¼ sec. 10, T. 73 N., R. 18 W., Monroe County, Iowa.

Repository.—State University of Iowa, Catalogue Nos. 846-853, 861-868 (cotypes); the figured specimens are Nos. 849-853 and 864-868.

FUSULINA? PROBLEMATICA Thompson, n. sp.

Plate XXI, figures 6, 9, 11, 16, 17

Shell minute, short, uniformly fusiform, with rather sharply pointed poles, with straight axis of coiling, and with shallow external furrows. The length of mature specimens is about 2.70 mm and the width is about 1.25 mm. The form ratio is about 1:1.9 in the third volution, 1:2.1 in the fourth volution, 1:2.3 in the fifth volution, and 1:2.2 in mature forms of 6 volutions.

The septa are very thick and are composed of an anterior tectorium, a tectum, a diaphanotheca, and a posterior tectorium. The anterior and posterior tectoria are very thick near the base of the septa and are relatively thin near the top of the chambers. They are the continuations of the tectoria of the spirotheca. The tectum is very thin and dense and is the downward extension of the tectum of the spirotheca of the preceding chamber; however, it is not distinguishable in the lower part of the septa. The diaphanotheca is thin and light and is the downward continuation of the diaphanotheca of the spirotheca of the preceding chamber. The external furrows are essentially straight in the mid-portion of the shell but near the poles they make a slight backward twist. The septa are broadly but rather highly fluted in the polar portions of the shell, but in the median half of the shell they are more broadly fluted. In the polar region the septa are fused at the points of approach of the flutings apparently to the top of the chamber whereas in the median portion of the shell the fusions reach only about three-fourths the height of the chamber. The septal count is about 17 for the second volution, 22 for the third volution, 26 for the fourth volution, and 31 for the fifth volution.

The early stage of development (the "juvenarium") of this species is unusual for this genus in that the proloculum is very minute, about 15 microns in diameter, and the early chambers are added in a slightly involute coil of about two and one-half volutions with its axis of coiling almost at right angles to the axis of coiling of the outer fusulinid coils. The diameter of the proloculum plus these inner two and one-half coils is about 100 microns. In the above measurements of the form ratio and the determination of the septal counts the first volution is taken as the first fusulinid type of coil. The form ratio of these inner two and one-half coils is about 2:1. The inner two and one-half fusulinid volutions are slightly more tightly coiled than the outer volutions.

The spirotheca is very thick. It is composed of an upper tectorium, a tectum, a diaphanotheca, and a lower tectorium. The upper tectorium is very thick and dense. It is about 25 microns thick in the fifth volution beyond the limits of the chomata, and it thickens toward the poles where it, combined with the tectoria of the septa, fills the chambers for about one-fourth the height of the septa. The tectum is very thin and dense. The diaphanotheca is about 5.0 microns thick in the sixth volution, but it is rather indistinct in most sections. The lower tectorium is about 5.0 microns thick over the line of the tunnel, but it rapidly thins poleward to merely a dark line as seen in thin-sections. The lower one-fourth of the upper tectorium of the median part of the shell is of about equal density to the diaphanotheca and the upper three-fourths is about equal in density to the lower tectorium.

The tunnel is narrow and high and its line of intersection with axial sections is very irregular. The tunnel is about one-half the height of the chambers and about one-half as high as wide. Either side of the tunnel is bordered by a vertical wall formed by the inner edge of a ridge, the choma, which has a gentle outer slope, and which in the fifth volution completely fills some of the chambers immediately adjacent to the tunnel. The choma is composed of material similar in density to the upper part of the upper tectorium. The floor of the tunnel is covered by tectorium that is about 23 microns thick in the sixth volution. The tunnel angle is 15 to 22 degrees.

This species is very doubtfully referred to the genus *Fusulina*. The relatively thick upper tectorium and the well developed chomata suggest that its affinities are with *Fusulinella*; but the septa are fluted, though very broadly so, throughout the length of the shell which suggest relationship to *Fusulina* s. s. However, an endothyroid-like coil has not been found in any species previously referred to *Fusulina*—such a coil is known however to occur in the Permian genera *Neofusulinella, Depratella,* and *Yangchienia* and in forms from the lower Pennsylvanian that have been referred to the genus *Schubertella*. Also, Lee has stated that forms from the Orient, which he considered conspecific with the genotype of *Fusulinella, F. bocki,* have such an early development. Lee considers that this is merely a result of dimorphism or even trimorphism and that it is not a generic or even a specific character. A large number of specimens from the type localities of *F. problematica* have

been secured and in no case have forms been found with a normal large proloculum and fusiform early volutions which have a spirotheca and chomata structure and septal fluting like *F. problematica.* Furthermore, it does not seem that dimorphism has at all been demonstrated in the fusulinids, and from horizons in which only a single species occurs, such as that from which *Fusulinella iowensis* was obtained, large numbers of sections have in no case given any evidence of dimorphic forms. This is also true of horizons in which a number of species occur. It seems that the early asymmetrical endothyroid-like coils of this species, combined with its other characters, is very probably of generic significance and this species therefore represents an unnamed genus.

The structure of the spirotheca of *F. problematica* is quite different from that of *Schubertella* as originally described by Staff and Wedekind for they state that it is composed of only one layer; also, the original illustrations of *S. transitoria*, the genotype of *Schubertella,* do not show an early endothyroid coil like that of *F. problematica,* though Staff and Wedekind state that the inner whorls are ''endothyrisch''. The thin diaphanotheca, thick tectoria, and fluted septa of *F. problematica* distinguish it generically from typical representatives of the genera *Neofusulinella, Depratella,* and *Yangchienea. F. problematica* differs generically from the genotype of *Boultonia, B. willsi* Lee, for its spirotheca has four layers whereas *B. willsi* has only two layers. Also, its shell is much shorter and its chomata are better developed.

Occurrence.—My collections from Iowa contain representatives of this species from a thin limestone about 35 feet below the White Breast coal in the bank of a small northeast-flowing creek, 75 yards west of the west edge of Wapello County, NE¼SE¼ sec. 13, T. 72 N., R. 16 W., Monroe County, Iowa (pl. XXI, fig. 17); and from the same horizon in the south bank of a small west-flowing creek, 12 feet above the bed of the creek, 75 yards south of County road L, ½ mile west of Lovilia, SW¼ sec. 10, T. 73 N., R. 18 W., Monroe County; and from a calcareous shale 1½ feet below the limestone mentioned above, in the west road-ditch, on the east line of Lucas County, near the top of a north-sloping hill, SE¼ sec. 1, T. 73 N., R. 20 W. (pl. XXI, figs. 6, 9, 11, 16).

Repository.—State University of Iowa, Catalogue Nos. 869-877 (cotypes); the figured specimens are Nos. 873-877.

Fusulina lucasensis Thompson, n. sp.

Plate XXII, figures 2, 9, 12, 17, 19

Shell minute, short, uniformly fusiform with bluntly pointed poles, and with straight axis of coiling. Mature specimens of 7 to 7½ volutions are about 3.0 mm in length and 1.25 mm in width, giving a form ratio of 1:2.4. Rarely more gibbous forms are found that give a form ratio of 1:2.1 at maturity. The form ratio is 1:1.9 for the third volution, 1:2.0 for the fourth volution, 1:2.2 for the fifth volution, and 1:2.3 for the sixth volution. The lateral slopes are convex and uniform.

The septa are thick and are composed of two outer thick layers of tectoria, a tectum, and a diaphanotheca. The diaphanotheca measures 11.0 microns in the sixth volution. The septa are 40 microns thick in the sixth volution about midway between the tunnel and the pole. The tectoria are much denser than the diaphanotheca except the posterior one-fifth of the anterior tectorium which is about equal in density to the diaphanotheca. The tectoria of the septa combined with the tectoria of the spirotheca fuse the walls of the chambers in the polar regions where the chambers are very short. The external furrows are straight throughout the length of the shell, but the septa are broadly but highly fluted from pole to pole. The average septal count is about 16 for the second volution, 20 for the third volution, 25 for the fourth volution, 26 for the fifth volution, and 27 for the sixth volution.

The proloculum is sub-spherical and is very small, measuring only 42 to 60 microns in diameter. The entire shell is tightly coiled but the inner two and one-half volutions appear to be more tightly coiled than the outer volutions.

The spirotheca is relatively thick. The diaphanotheca is very thick in comparison with the size of the specimen and measures about 12 microns in the sixth volution. The thickness of the upper tectorium is about five times that of the lower tectorium. In the center of the tunnel of the sixth volution the upper tectorium is 11.5 microns in thickness, whereas, about midway between the tunnel and pole it is 18 microns thick. The lower one-fourth of the upper tectorium is much lighter than the remainder of this layer and is of about the same density as the diaphanotheca on the opposite side of the tectum.

The tunnel is about one-fourth as high as wide and about one-half to one-third as high as the chamber in the sixth volution, and

its intersection with axial sections is slightly irregular. Determinations of the tunnel angle based on measurements in the sixth volution give 30 to 35 degrees with an average of about 33 degrees. The tunnel is bordered by ridges, chomata, that are about one-half the height of the chambers in all volutions except the last. In the outer volution the chomata are very low or indistinct.

Fusulina lucasensis seems to be more closely related to *Fusulina kayi*, n. sp., than to any other described species. In *F. lucasensis* the diameter of the proloculum is 42 to 60 microns whereas the diameter of that of *F. kayi* is about 90 microns. The tunnel angle of *F. lucasensis* is larger than the tunnel angle of *F. kayi*. Also *F. lucasensis* differs from *F. kayi* in that it has a much thicker diaphanotheca. *F. lucasensis* can be distinguished from other similar species by its small size, relatively very small proloculum, thick spirotheca, and large tunnel angle.

F. lucasensis resembles in a general way *Fusulina haworthi* White [not *Fusulinella haworthi* Dunbar and Condra] from the top of the Millsaps formation of Texas, but it seems to differ from that species particularly in that the septa of *F. lucasensis* are not so highly fluted as are those of the Texas species; the Iowa specimens are slightly smaller; and the external views of the Texas species show an inflation in the central one-third of the shell which is not found in *F. lucasensis*.

Occurrence.—This species has been found rather abundant at only one horizon and locality in a limestone about 10 feet above a thin coal which apparently is the second coal beneath the Mystic coal. The collections were obtained from the south bank of a small west-flowing creek, about 15 feet above the bed of the creek, SW¼-NE¼ sec. 16, T. 72 N., R. 22 W., Lucas County, Iowa.

Repository.—State University of Iowa, Catalogue Nos. 878-884 (cotypes); the figured specimens are Nos. 881-884.

FUSULINA EURYTEINES Thompson, n. sp.

Plate XXII, figures 4, 13, 14, 18

Fusulinella meeki Dunbar and Condra, *1927*, Nebraska Geol. Survey Bull. 2, ser. 2, pp. 78-80, pl. 15, figs. 4-6, and (?) pl. 2, figs. 12-14. [not *Fusulina ventricosa meeki* Möller, 1879]

(?) *Fusulinella* n. sp. Henbest, *1928,* Jour. Pal., Vol. 2, p. 79, pl. 10, figs. 2, 4.

(?) *Fusulina meeki* White, *1932,* Texas Univ. Bull. 3211, pp. 27-30, pl. 1, figs. 7-12.

Shell small, moderately short, with bluntly pointed poles, and slightly inflated in the central one-half. The shell is constricted near the poles and the extreme ends are slightly inflated in mature forms. The axis of coiling is essentially straight and the external furrows are very shallow. Mature forms of 7 volutions are 4.3 to 4.7 mm in length and 2.0 to 2.1 mm in width, giving a form ratio of about 1:2.2. The form ratio is 1:1.9 in the third volution, 1:2.1 for the fourth volution, 1:2.2 for the fifth volution, and 1:2.1 for the sixth volution.

The septa are rather thick. The diaphanotheca is about 15 microns thick in the sixth volution. The tectoria are more dense than the diaphanotheca and are continuous with the two outer layers, tectoria, of the spirotheca. The posterior one-fifth of the anterior tectorium is about equal in density to the diaphanotheca on the opposite side of the tectum. This lighter portion of the anterior tectorium is very similar in thickness and nature to the lower light part of the upper tectorium of the spirotheca. The external furrows are essentially straight to broadly curved. The lower four-fifths of the septa are broadly fluted near the center of the shell, but they become very narrowly and highly fluted near the poles. There are 25 septa in the third volution, 28 in the fourth volution, and 31 in the fifth volution.

The proloculum is essentially spherical and it is 95 to 125 microns in diameter. The rate of increase of the height of the chambers is essentially uniform throughout the development of the individual.

The spirotheca is thick and is composed of an upper and lower tectorium, a tectum, and a diaphanotheca. The diaphanotheca is about 18 microns thick in the sixth volution. The upper tectorium is about 28 microns thick in the sixth volution beyond the limits of the chomata, and it is three to four times as thick as the lower tectorium in the same position. The lower one-third of the upper tectorium is only slightly denser than the diaphanotheca. The tectoria of the spirotheca and septa tend to fill the chambers in the polar regions of the first four volutions but these layers are relatively thin in the polar zones of the last three volutions.

The line of intersection of the tunnel with axial sections is very

irregular and the tunnel angle is 23 to 27 degrees. The tunnel is one-third to one-fourth the height of the chamber and it is about one-fourth as wide as high in the sixth volution. Either side of the tunnel is bordered by a ridge of material, choma, that is very similar in density to the tectoria, and this ridge is one-half to two-thirds the height of the chambers in all volutions except the last one and one-half or two.

Fusulina euryteines is more nearly similar to *F. stookeyi*, n. sp., than any other described species. In general shape and measurements they are very similar, but they can be readily distinguished by their internal structures. The septa of *F. euryteines* are more broadly and less highly fluted than are those of *F. stookeyi*; also the proloculum is smaller and the tectoria and the chomata are better developed in *F. euryteines* than in *F. stookeyi.*

The specimens included under this species are clearly conspecific with the specimens from the Cherokee near Rich Hill, Missouri, described and illustrated by Dunbar and Condra as *Fusulinella meeki.* However, we now know that this form is a representative of the genus *Fusulina* s. s.; therefore, the name *Fusulina meeki* (Dunbar and Condra) becomes a homonym of *Fusulina ventricosa meeki* Möller. There is some question as to the relationship between the specimens from the Millsaps formation of Texas illustrated and described by Dunbar and Condra as *Fusulinella meeki* and by White as *Fusulina meeki* and the Iowa specimens which I am making the types of *Fusulina euryteines.*

Occurrence.—Representatives of this species have been found in Iowa in only one horizon, a thin limestone about 35 feet below the White Breast coal. I have collected specimens from this limestone on the south bank of a small west-flowing creek, 12 feet above the bed of the creek, 75 yards south of County road L, ½ mile west of Lovilia, SW¼ sec. 10, T. 73 N., R. 18 W., Monroe County (pl. XXII, figs. 4, 13, 14, 18); in the west road-ditch, on the east line of Lucas County, near the top of a north-sloping hill, SE¼ sec. 1, T. 73 N., R. 20 W.; in the north road cut of United States highway 34, at the top of a west-sloping hill, SE¼ sec. 13, T. 72 N., R. 16 W., Monroe County; and in the east bank of a small northeast-flowing creek, 75 yards west of the edge of Wapello County, NE¼-SE¼ sec. 13, T. 72 N., R. 16 W., Monroe County. Dunbar and Condra have described conspecific specimens from the Cherokee near Rich Hill, Missouri, and Dunbar and Condra and White have

described and illustrated some specimens from the Millsap formation of Texas that may represent it. Also Henbest has briefly described and illustrated a form from the Stonefort limestone of southern Illinois that may be conspecific.

Repository.—State University of Iowa, Catalogue Nos. 885-896 (cotypes); the figured specimens are Nos. 893-896.

FUSULINA PUMILA Thompson, n. sp.

Plate XXII, figures 6, 8, 10, 11

Shell small, short, uniformly fusiform, with bluntly pointed poles, straight external furrows, and straight axis of coiling. The average form ratio as determined by 9 typical axial sections is about 1:2.0 in the third and fourth volutions, and 1:1.8 in the fifth and sixth volutions. Mature forms of 7 volutions are about 3.1 mm in length and 1.8 mm in width.

The septa are relatively thick and are composed of an anterior and posterior tectorium, a diaphanotheca, and a tectum. The diaphanotheca is about 8.0 microns thick in the sixth volution. The posterior side of the anterior tectorium for about one-third its thickness is very similar in density to the diaphanotheca on the opposite side of the tectum. The external furrows are straight and the septa are broadly and highly fluted throughout the length of the shell. The septa are fused at points of approach for about three-fourths the height of the chambers midway between the tunnel and the poles. The septal count is about 21 for the second volution, 23 for the third volution, 26 for the fourth volution, 32 for the fifth volution, and 34 for the sixth volution; these counts may vary from these figures as much as 3 in the fourth and fifth volutions.

The proloculum is small and is between 70 and 110 microns in diameter with an average nearer the smaller figure. The rate of increase of the height of the antetheca is uniform throughout the development of the individual.

The spirotheca is relatively thick. In the sixth volution the upper tectorium is about 30 microns thick midway between the tunnel and pole and about 15 microns thick in the center of the tunnel. In the sixth volution the lower tectorium is 10 microns thick about midway between the tunnel and pole. The diaphanotheca is much less dense than the tectoria, however the lower one-fourth of the upper tectorium is very similar in density to the dia-

phanotheca. The diaphanotheca is about 7.5 microns thick in the sixth volution.

The tunnel is very high and narrow, and it is about one-half the height of the chambers and one-third as high as wide. The floor of the tunnel is covered by the thick upper tectorium of the spirotheca. Either side of the tunnel is bordered by an asymmetrical ridge, the choma, which is about three-fourths the height of the chambers and which thins rather rapidly poleward. The line of intersection of the tunnel with axial sections is rather irregular and the tunnel angle, as shown by determinations made in the sixth and seventh volutions, is 16 to 19 degrees.

Fusulina pumila is somewhat similar in general shape to *F. girtyi* but it differs from that species particularly in that it is much smaller, its septa are not so highly fluted, and its tectoria are better developed. *F. pumila* differs from *F. euryteines* in that its axis is much shorter, its tunnel angle is smaller, and the septal fluting of the two species is different. *F. pumila* differs from *F. problematica* in that it is larger, its form ratio is larger, its inner volutions are quite different, and its spirotheca is thinner than that of *F. problematica*. *F. pumila* is larger, has a smaller form ratio, smaller tunnel angle, and more numerous septa than *F. tregoensis* Roth and Skinner.

Occurrence.—This species has been found in Iowa in only a thin limestone about 35 feet below the White Breast coal. My collections contain specimens from the north bank of United States highway 34, near the top of a west-sloping hill, SE¼SW¼ sec. 13, T. 72 N., R. 16 W., Monroe County; in the bed of a small northeast-flowing creek, 75 yards west of the Wapello County line, NE¼SE¼ sec. 13, T. 72 N., R. 16 W.; Monroe County (pl. XXII, figs. 6, 8, 10, 11); and from the south bank of a small west-flowing creek, 75 yards south of County road L, 12 feet above the bed of the creek, ½ mile west of Lovilia, SW¼ sec. 10, T. 73 N., R. 18 W., Monroe County.

Repository.—State University of Iowa, Catalogue Nos. 897-905 (cotypes); the figured specimens are Nos. 902-905.

FUSULINA GIRTYI (Dunbar and Condra)

Plate XXII, figures 1, 5, 7, 20

Fusulina ventricosa Meek and Worthen, *1873*, Illinois Geol. Survey, vol. 5, p. 560, pl. 24, figs. 8a and 8b. [not *Fusulina ventricosa* Meek and Hayden, 1858]

Fusulina ventricosa Meek, *1874,* Am. Jour. Sci., ser. 3, vol. 7, p. 484.
Girtyina ventricosa v. Staff, *1912,* Palaeontographica, vol. 59, pp. 164-165, pl. 18, figs. 2, 5, and 7.
Girtyina ventricosa Cady, *1925,* Illinois Geol. Survey, Rept. of Investigation, no. 2, p. 8, text fig. 2, A and B.
Fusulinella girtyi Dunbar and Condra, *1927,* Nebraska Geol. Survey Bull. 2, ser. 2, pp. 76-78, pl. 2, figs. 1-5.
Fusulinella (Girtyina) ventricosa Henbest, *1928,* Jour. Pal., vol. 2, p. 83, pl. 9, figs. 3, 4, 6, and 6a. [not pl. 10, figs. 5, 6, and 7]
Beedeina girtyi Galloway, *1933,* Manual of Foraminifera, p. 401, pl. 36, fig. 17.

The collections from Iowa that I am studying contain a large number of well preserved representatives of this species. However, this species has been adequately described by Dunbar and Condra, and since this publication is readily accessible to most paleontologists it is not necessary to duplicate their work.

The specimens which I am studying agree very closely with the illustrations and descriptions of Dunbar and Condra's cotypes from the roof of Coal No. 6, near Canton, Fulton County, Illinois. The form ratio of the Iowa specimens is about 1:1.6 in the third volution, and 1:1.5 in the remaining outer 6 volutions of mature forms, and mature forms are about 4.3 mm in length and 2.8 mm in width. The tunnel angle is about 14 degrees, and either side of the tunnel is bordered by heavy deposits, the chomata, of dense calcite that are very similar in character to the tectoria. In the earlier volutions these deposits form into asymmetrical ridges that border the tunnel and slope downward toward the poles. In the outer volutions these deposits, chomata, are irregular posterior-anteriorly and do not seem to form into definite ridges from one chamber to the next; however, in many of the chambers immediately adjacent to the tunnel there is only a small circular opening left near the top of the chamber. The septal count of the Iowa forms agrees very closely with that of the Illinois specimens in the third and fourth volutions, but some of the Iowa specimens have as high as 45 septa in the fifth volution and 54 septa in the sixth volution—the average is much nearer the figures given by Dunbar and Condra, 38 and 41 respectively. The proloculum of the Iowa specimens is about 140 microns in diameter with an average a little less than this figure.

Fusulina girtyi externally seems more nearly similar to *Fusulina*

pumila, n. sp., than to any other described species. It differs from this species in that it is much larger, it contains more numerous volutions, its walls are relatively thinner, its septal fluting is different, its proloculum is much larger, and its tunnel angle is smaller. *F. girtyi* occurs associated with *Fusulina stookeyi*, n. sp., from which it may be distinguished by the difference in the shape of the shell, the shortness of *F. girtyi* as compared with *F. stookeyi*, the difference in the nature of the septal fluting, the difference of the development of the spirotheca, and the difference in the tunnel angle. The close association of these two species, *F. girtyi* and *F. stookeyi*, would suggest that they may be merely dimorphic expressions of the same species. However, the fact that in one place at least *F. stookeyi* is extremely abundant and *F. girtyi* is very rare seems to support my conclusion that they represent distinct species.

Occurrence.—*Fusulina girtyi* is known to occur in Iowa in only the so-called "eighteen-foot limestone" [18 feet above the Mystic coal]. It has been found at five different localities, which are as follows: ten feet above the bed of a small north-flowing creek, near an old mine drift, NE¼ sec. 1, T. 70 N., R. 17 W., Appanoose County (pl. XXII, figs. 1, 5, 7, 20); in the bed of a creek 50 yards north of County road S, 2 miles northeast of Moravia, NW¼ sec. 35, T. 71 N., R. 17 W., Monroe County; on the south bank of Fish Branch, NE¼ sec. 28, T. 70 N., R. 19 W., Appanoose County; on the south bank of Chariton River, east bank Iowa highway 60, NW¼SW¼ sec. 7, T. 69 N., R. 17 W., Appanoose County; and in the bed of County road G, ¼ mile west of Brazil, SW¼ sec. 20, T. 69 N., R. 18 W., Appanoose County. Representatives of this species have been found in the "roof rock" of Coal No. 6 of the Carbondale formation of Illinois and in the Fort Scott limestone at Oswego, Kansas.

Repository.—State University of Iowa, Catalogue Nos. 919-927 (plesiotypes); the figured specimens are Nos. 924-927.

FUSULINA STOOKEYI Thompson, n. sp.

Plate XXII, figures 3, 15, 16, 21

Shell small, short, fusiform, with bluntly pointed poles; the central one-half is inflated. The axis of coiling is slightly irregular. Approximately one-fifth the distance from the poles the shell is slightly constricted and the lateral slopes are slightly concave. The

external furrows are shallow. Mature forms consist of 7 to 7½ volutions and are 5.1 to 5.5 mm in length and 2.5 to 2.8 mm in width. The form ratio is 1:1.8 to 1:2.4 in the third volution, 1:1.8 to 1:2.3 in the fourth volution, 1:1.9 to 1:2.2 in the fifth volution, and 1:1.9 to 1:2.2 in the sixth volution: the average form ratios for these volutions are 1:1.9, 1:1.9, 1:2.0, and 1:2.1 respectively. In some of the more elongate forms the poles are sharply pointed and are drawn out in the third, fourth, and fifth volutions; this, of course, results in abnormally small form ratios for these volutions.

The septa are very narrowly and highly fluted throughout the length of the shell and the chambers are divided into chamberlets which reach approximately four-fifths the height of the chambers. The fusions between the chamberlets do not seem to extend to the base of the septa due to a slight reversal of the fluting before reaching the spirotheca of the preceding volution. There are 21 septa in the second volution, 24 in the third volution, 28 in the fourth volution, 32 in the fifth volution, 39 in the sixth volution, and 44 in the seventh volution. The septa are very thin in the polar one-fourth of the shell and have very thin tectoria. In the central one-half the septa are coated with upward extensions of the chomata that decrease in thickness very rapidly from the tunnel poleward.

The proloculum is of medium size and measures about 140 microns in diameter. The inner two and one-half to three volutions of this species are tightly coiled and the outer volutions are more loosely coiled.

The spirotheca or wall is relatively thin. The diaphanotheca is very light and translucent, and it increases in thickness from a very thin layer in the first volution to about 22 microns near the tunnel in the seventh volution. The upper tectorium is about 14 microns thick near the tunnel of the sixth volution, and it decreases to a very thin layer near the poles. The lower tectorium is well developed over the line of the tunnel but it decreases rapidly in thickness poleward and in the polar regions it cannot be discerned. The lower part of the upper tectorium of the spirotheca as well as the posterior part of the anterior tectorium of the septa are about equal in density to the diaphanotheca on the opposite side of the tectum.

The tunnel is broad and low and is about one-third the height of the chambers and about one-fifth as high as broad in the seventh volution. The tunnel angle as determined in the sixth volution is 20 to 28 degrees with an average of about 24 degrees. The chomata

are in the form of high, narrow, broadly rounded ridges which flank either side of the tunnel in the earlier volutions, but in the outer three volutions they are more irregular and do not form continuous uniform ridges. In these outer volutions the upper part of the spirotheca and the lower part of the septa are coated with dense granular calcite near the tunnel; this thins rapidly poleward.

Fusulina stookeyi externally is very similar to *Fusulina euryteines.* These two species agree very closely in size and measurements but their internal structures are very different. The fluting of *F. stookeyi* is very narrow and high whereas that of *F. euryteines* is relatively broad and low—these characters alone are sufficient to distinguish the two species. The proloculum of *F. euryteines* is smaller than that of *F. stookeyi,* the chomata are better developed in *F. euryteines,* and the tectoria of the two species are different. *F. stookeyi* differs from *Fusulina similis* Galloway and White in that it is larger than that species, its proloculum is larger, its septal fluting is different, and the general shape and form ratios of the shells are quite different.

This species is named in honor of Mr. Donald G. Stookey, who is studying the Pennsylvanian rocks of Iowa and who was the writer's field companion when the specimens on which this report is based were collected.

Occurrence.—This species occurs very abundantly in the so-called "eighteen-foot limestone" [18 feet above the Mystic coal] but it is confined to that horizon. I have found it in the south bank of Chariton River, east side of Iowa highway 60, SE¼ sec. 7, T. 69 N., R. 17 W., Appanoose County, Iowa; on the west bank of a small north-flowing creek, NE¼ sec. 1, T. 70 N., R. 17 W., Appanoose County, Iowa (pl. XXII, fig. 15); in the bed of County road G, ¼ mile west of Brazil, north side SW¼ sec. 20, T. 69 N., R. 18 W., Appanoose County, Iowa; in the east cut-bank of County road K, eighteen feet above the bed of the road, SW¼SW¼ sec. 16, T. 67 N., R. 16 W., Appanoose County, Iowa; and in the bed of a small creek, fifty yards north of County road S, 2 miles northeast of Moravia, NW¼ sec. 35, T. 71 N., R. 17 W., Monroe County, Iowa (pl. XXII, figs. 3, 16, 21).

Repository.—State University of Iowa, Catalogue Nos. 906-918 (cotypes); the figured specimens are Nos. 915-918.

FUSULINA MYSTICENSIS Thompson, n. sp.
Plate XXIII, figures 1-3

Shell large, elongate, fusiform to sub-cylindrical, with bluntly pointed poles. In profile representatives of this species are variable, but sub-cylindrical forms with very bluntly pointed poles are the more common. Mature forms consist of 8½ to 9 volutions and they are 8.5 to 10.2 mm in length and 2.6 to 3.0 mm in width. The form ratio of mature specimens is 1:4.0 to 1:3.0, with an average closer to the larger ratio. The average form ratio of 14 specimens is 1:2.5 for the third volution, 1:2.7 for the fourth volution, 1:3.0 for the fifth volution, 1:3.3 for the sixth volution, and 1:3.2 for the seventh volution. The shell is fusiform in the inner six volutions and the poles are sharply pointed, but in the outer volutions the poles become very bluntly rounded and the lateral slopes are very gentle.

The septa are thin. The tectoria are very thin near the poles but they appear to be relatively thick near the tunnel; this increase in thickness near the tunnel is due to the addition of material probably from the chomata. The diaphanotheca is less dense than the tectoria in the upper part of the septa but in the lower part of the septa it appears more dense and is not distinguishable from the tectoria. The external furrows are essentially straight. The septa are very narrowly and highly fluted throughout the length of the shell, but in the mid-portion of the shell the fluting is slightly broader than it is near the poles. The septal count varies considerably for different individuals. The average septal count for 7 sagittal sections is 23 for the second volution, 28 for the third volution, 30 for the fourth volution, 35 for the fifth volution, 39 for the sixth volution, and 43 for the seventh volution. The variations for these different volutions are 18 to 28, 25 to 31, 29 to 33, 31 to 37, 35 to 45, and 40 to 53, respectively.

The proloculum is sub-spherical and is 130 to 175 microns in diameter. The inner two volutions are very tightly coiled about the proloculum, in the third volution the coiling is somewhat less tight and beyond the third volution the chambers become noticeably higher.

The spirotheca is of medium thickness for the genus. The tectoria are thin, they are of about equal thicknesses, and they are composed of rather dense calcite. In the seventh volution beyond the limits of the chomata they are about 5 microns thick. The diaphanotheca

is of translucent calcite and it is about 18.7 microns thick in the seventh volution near the tunnel.

The tunnel is one-third to one-half the height of the chamber and about one-fifth as high as wide in the seventh volution. The tunnel angle is 21 to 32 degrees in the seventh volution, with an average of about 26 degrees. The chomata are in the form of very asymmetrical ridges in the inner five volutions, but in the outer volutions the deposits are rather irregular and they cover the upper part of the spirotheca and the septa with rapidly decreasing thicknesses for about one-fourth the distance from the tunnel to the poles.

Fusulina mysticensis is more nearly similar to *Fusulina megista*, n. sp., than any other described species, but it may be distinguished from that species by its smaller form ratio, more elongate shell, and larger tunnel angle. *F. mysticensis* and *F. megista* are associated together in the same limestone and gradational forms more or less intermediate between the types here figured are found, and it is possible that *F. megista* is merely a variety of *F. mysticensis*.

Occurrence.—This species is found rather abundantly in the so-called "fifty-foot limestone" [50 feet above the Mystic coal] of Appanoose County, Iowa; I have found representatives of it in the east valley wall of Shoal Creek, 3¼ miles east of Cincinnati, in the south ditch of County road C, SW¼ sec. 6, T. 67 N., R. 17 W. (pl. XXIII, figs. 1-3); in the south edge of the town of Mystic, fifty feet above Walnut Creek, SW¼ sec. 16, T. 69 N., R. 18 W.; beneath the bridge of County road P, Chariton River, SE¼ sec. 9, T. 70 N., R. 19 W.; in the south ditch of Iowa highway 3, 1½ miles west of Sunshine, NE¼NW¼ sec. 32, T. 69 N., R. 18 W.; and ¼ mile south of Iowa highway 3, east edge NW¼ sec. 34, T. 69 N., R. 19 W.

Repository.—State University of Iowa, Catalogue Nos. 943-953 (cotypes); the figured specimens are Nos. 951-953.

FUSULINA MEGISTA Thompson, n. sp.

Plate XXIII, figures 4-6

(?) *Fusulinella meeki robusta* Dunbar and Condra, *1927*, Nebraska Geol. Survey Bull. 2, ser. 2, pp. 80-82, pl. 15, figs. 7, 8.

Shell large, somewhat elongate and robust, with bluntly pointed

poles, with straight axis of coiling, and with shallow external furrows. Mature specimens of 9 to 9½ volutions are 6.4 to 8.5 mm in length and 3.2 to 3.5 mm in width. The form ratio is about 1:2.0 in the third volution, 1:2.1 in the fourth volution, and 1:2.3 in the fifth, sixth and seventh volutions. Mature specimens have a form ratio of 1:2.5 to 1:2.0 with an average nearer the smaller ratio. The profile of this species is rather uniform throughout the growth of the individual and the lateral slopes are slightly convex in most of the specimens, but some specimens have been found that have slightly concave lateral slopes near the poles.

The septa are relatively thick and are composed of an anterior and posterior tectorium, a tectum, and a diaphanotheca. The diaphanotheca and tectum are of about the same thicknesses as the tectum and diaphanotheca of the spirotheca. The tectoria of the septa are well developed in the region of the tunnel but they rapidly thin poleward. There are about 23 septa in the second volution, 26 in the third volution, 32 in the fourth volution, 39 in the fifth volution, 45 in the sixth volution, and 48 in the seventh volution. The external furrows are essentially straight from pole to pole. The septa are very narrowly and highly fluted throughout the length of the shell, and the fluting divides the chambers into chamberlets. The fusions of the septa that separate the chamberlets reach to about four-fifths the height of the chambers, and in many cases the fusions do not reach completely to the floor of the chambers.

The proloculum is spherical to sub-spherical and is 140 to 200 microns in diameter, with an average of about 170 microns. The inner three to three and one-half volutions are very tightly coiled about the proloculum but the outer volutions have higher septa. This change in manner of coiling takes place through about one-half volution.

The spirotheca is of moderate thickness for the genus. The upper tectorium is about 15 microns thick in the center of the tunnel of the sixth volution, it becomes somewhat thicker immediately on either side of the tunnel, but it is extremely thin in the polar regions. The lower tectorium is best developed immediately over the tunnel where it is 8 to 10 microns thick in the sixth volution and it is very thin or even absent toward the poles of the outer four volutions. The diaphanotheca increases in thickness uniformly from a very thin layer in the first volution to about 19 microns in the sev-

enth volution near the line of the tunnel. The different layers of the spirotheca, in the order of their densities, are tectum, tectoria, and diaphanotheca. However, the lower part of the upper tectorium of the spirotheca as well as the posterior side of the anterior tectorium of the septa are of about the same density as the diaphanotheca.

The tunnel is of moderate height and it is relatively narrow. The line of intersection of the tunnel with axial sections is very irregular and the tunnel angle, as determined in the eighth volution, is 15 to 18 degrees. The tunnel is bordered on either side by deposits, the chomata, that form asymmetrical ridges in the inner volution, but they become more irregular in the outer volutions and do not form definite ridges. These deposits show in axial sections of the outer four volutions as more dense portions of the shell, due to the abnormal thickness of the septa and the upper part of the spirotheca immediately adjacent to the tunnel.

Fusulina megista is more nearly similar to *F. mysticensis*, n. sp., than any other described species but it can be distinguished from that species by its shorter and thicker shell, its more nearly uniform profile in mature specimens, and its smaller tunnel angle.

Fusulina megista very closely resembles the forms from the Pawnee limestone of Kansas described by Dunbar and Condra as *Fusulinella meeki robusta,* and these specimens are probably conspecific with the Iowa specimens. However, since it is now known that *Fusulinella robusta* Dunbar and Condra is more closely related to *Fusulina cylindrica,* the genotype of *Fusulina,* than any other genotype the name *Fusulina robusta* (Dunbar and Condra) becomes a homonym of *Fusulina robusta* Meek, and hence the name *robusta* cannot be used for this species.

Occurrence.—This species has been found in only the so-called "fifty-foot limestone" [50 feet above the Mystic coal], from five different localities in Appanoose County, Iowa. These localities are: beneath the bridge over Chariton River of County road P, SE¼ sec. 9, T. 70 N., R. 19 W.; in the south ditch of Iowa highway 3, 1½ miles west of Sunshine, NE¼SW¼ sec. 32, T. 69 N., R. 18 W. (pl. XXIII, fig. 6); the south ditch of County road C, near the center SW¼ sec. 6, T. 67 N., R. 17 W. (pl. XXIII, figs. 4-5); and ¼ mile south of Iowa highway 3, east side NW¼ sec. 34, T. 69 N., R. 19 W. The specimens described by Dunbar and Condra as

"*Fusulinella meeki robusta*", which I believe are probably conspecific with the cotypes of *Fusulina megista,* came from the Pawnee limestone near Pawnee, Kansas.

Repository.—State University of Iowa, Catalogue Nos. 928-942 (cotypes); the figured specimens are Nos. 940-942.

FUSULINA EXIMIA Thompson, n. sp.

Plate XXIII, figures 7-10

Shell rather large for this genus, very elongate, and cylindrical, with bluntly rounded poles. The axis of coiling is irregular and the lateral slopes are irregular. The external furrows are very distinct though shallow. The form ratios of the inner four volutions vary considerably among the different specimens, but in the outer volutions the profiles are, though very irregular, somewhat similar. The inner four to four and one-half volutions are irregularly fusiform with sharply pointed poles, but the outer volutions are cylindrical to subcylindrical and the poles become more blunt. Mature forms of 8 to 8½ volutions are about 7.4 mm in length and 1.7 to 2.1 mm in width. The average form ratio of seven typical specimens is 1:2.8 for the third volution, 1:3.1 for the fourth volution, 1:3.6 for the fifth volution, 1:4.1 for the sixth volution, and 1:4.3 for the seventh volution. The form ratio of mature specimens is 1:3.5 to 1:4.4.

The septa of this species are very thin and are composed of only a tectum and diaphanotheca; however, both sides of the septa are partially covered by very thin discontinuous layers of rather dense granular calcite that probably correspond to the tectoria of other members of this genus. The tectum and the diaphanotheca of the septa are the downward continuations of the tectum and diaphanotheca of the spirotheca of the preceding volution. The tectum is very dense and thin, and the diaphanotheca is translucent and is only slightly thinner than the diaphanotheca of the spirotheca. The septa are covered above and on both sides of the tunnel by heavy layers of dense calcite which was probably secreted at the same time the chomata was formed. The line of the external furrow is broadly sinuous to straight. The lower portions of the septa are fluted throughout the length of the shell, but near the tunnel the fluting is very broad and the fusions of the septa are low. In the regions of the poles the fluting becomes narrow and high. Five typical sagittal sections give a septal count of 20 to 23 for the second volu-

tion, 23 to 26 for the third volution, 25 to 30 for the fourth volution, 28 to 36 for the fifth volution, 32 to 37 for the sixth volution, and 35 to 37 for the seventh volution. The averages for these same volutions are 21, 25, 28, 31, 34, and 36, respectively.

The proloculum is spherical to sub-ellipsoidal and is 100 to 155 microns in diameter. The inner two and one-half to three volutions are tightly coiled about the proloculum, but the rest of the shell is less tightly coiled.

The spirotheca is thin. The diaphanotheca is composed of relatively clear calcite and it increases in thickness from a very thin layer in the first volution to 15 microns near the tunnel of the seventh volution. The diaphanotheca is overlain by a thin layer, the tectum, of dense granular calcite. The tectum is overlain in places by a thin layer of lighter calcite that is not everywhere present but is found in the earlier volutions near the center of the shell. The diaphanotheca is underlain by a thin layer of dense calcite near the line of the tunnel that was probably secreted at the same time the chomata was formed.

The tunnel is very low and broad. It is about three-sevenths the height of the chambers and one-seventh to one-tenth as high as wide in the seventh volution. The intersection of the tunnel with axial sections forms a slightly irregular path. The tunnel angle is 28 to 52 degrees. The tunnel is bordered by well developed ridges, the chomata, which are essentially symmetrical and that are about one-third the height of the chamber and one-half as high as broad.

In general external appearances *Fusulina eximia* somewhat resembles *Fusulina mysticensis*, n. sp.; however, it differs from that species especially in that it is more elongate and smaller, its septa are very differently fluted, its spirotheca is thinner, and its tunnel angle is much larger. *F. eximia* is larger, more elongate, and quite different in shape from *Fusulina haworthi* White of the Millsaps formation of Texas.

Fusulina eximia is very similar to *Fusulinella haworthi* Dunbar and Condra from just below the Lonsdale limestone of Illinois, and it may be conspecific with that species; however, the Iowa specimens are more elongate and more nearly cylindrical, and the septa are apparently less highly fluted. It is possible that the specimens here described as *F. eximia* are conspecific with *Fusulina haworthi* (Beede) of the lower Fort Scott limestone at Fort Scott, Kansas. However, Beede's brief description of that species was not accom-

panied by an illustration and his types have apparently been misplaced. As there is some disagreement among paleontologists as to the exact nature of *F. haworthi* it seems that until the cotypes of that species are found or until good topotypes are illustrated and described it will be best to consider *F. eximia* as a distinct species.

The spirotheca of *F. eximia* differs from the more primitive representatives of *Fusulina* s. s., here described, primarily in that the layers of spirotheca are much thinner and the septal fluting is less highly developed across the median portion of the shell. The diaphanotheca is well developed, but no traces of aveoli are discernable. *F. eximia* seems to be somewhat intermediate between typical representatives of *Fusulina* and typical *Triticites,* but its septal fluting and spirotheca structure show its affinities to be closer to the genus *Fusulina.*

Occurrence.—Fusulina eximia has been found only in the upper one foot of calcareous shale immediately beneath the so-called "floating-rock" [about 80 feet above the Mystic coal], 1/8 mile north of Iowa highway 3, 1/8 mile west of the large creek, at the water-fall of a small east-flowing creek, 1 mile west by north of Centerville courthouse, SE1/4 sec. 26, T. 69 N., R. 18 W., Appanoose County, Iowa (pl. XXIII, figs. 7-10) ; and in the same horizon on the east bank of Iowa highway 60, in the northeast corner of the town of Centerville.

Repository.—State University of Iowa, Catalogue Nos. 954-961 (cotypes) ; the figured specimens are Nos. 958-961.

PLATE XX

All the specimens figured on this plate came from the middle and lower portion of the Cherokee of Southeastern Iowa.

Page

Figs. 1,2,7,9,12,13,17,22,24-27—*Wedekindellina euthysepta* (Henbest)? 282

1,2,12,13—Axial sections, x20; 17, 22,24-26—external views, x10; 7—tangential section, x20; 9,27—sagittal section, x20.

3,6,15,16,20,21—*Wedekindellina dunbari* Thompson, n. sp. 285

3—Tangential section showing unfluted septa, x20; 6—axial section, x20; 15,20—external views of slightly weathered specimens, x10; 16—external view showing unfluted antetheca, x20; 21—sagittal section, x20.

4,5,14,23—*Wedekindellina uniformis* Thompson, n. sp. 289

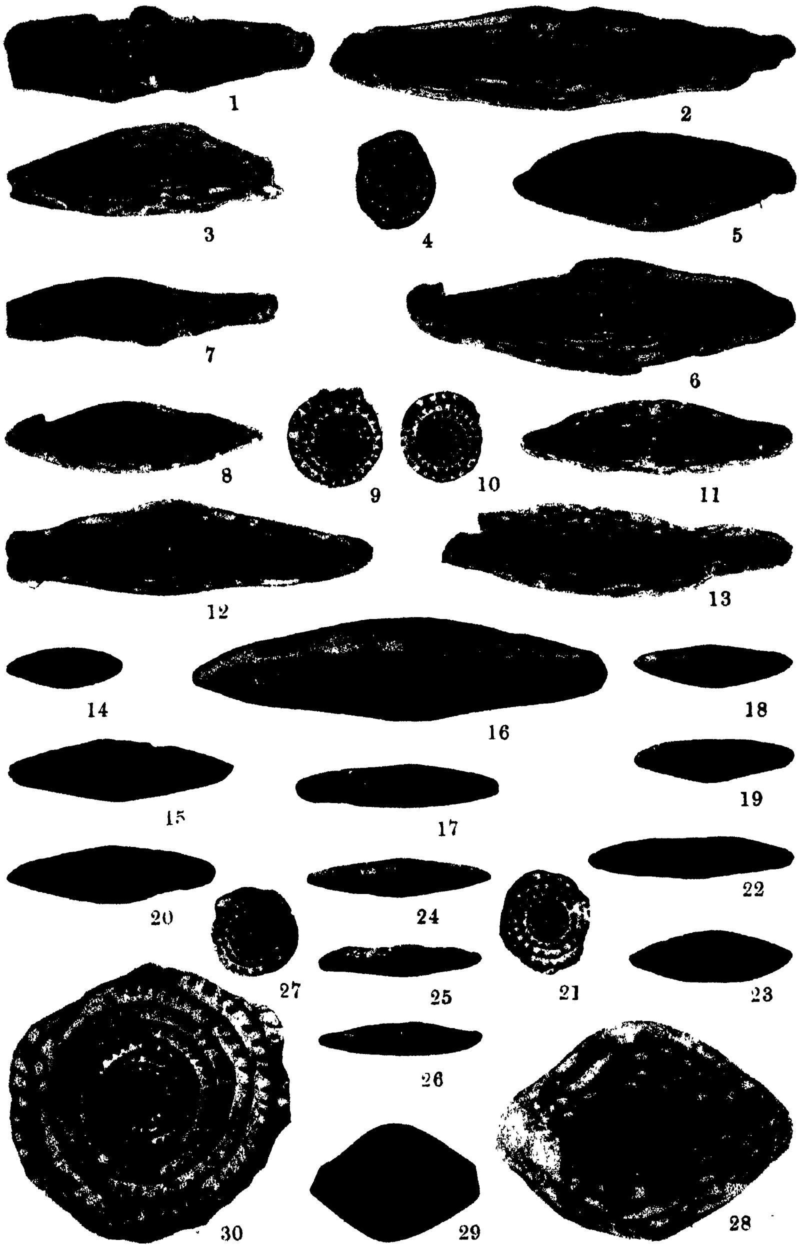
5—Axial section, x20; 14,23—external views of mature and sub-mature specimens, x10; 4—sagittal section, x20.

8,10,11,18,19—*Wedekindellina elfina* Thompson, n. sp. 287

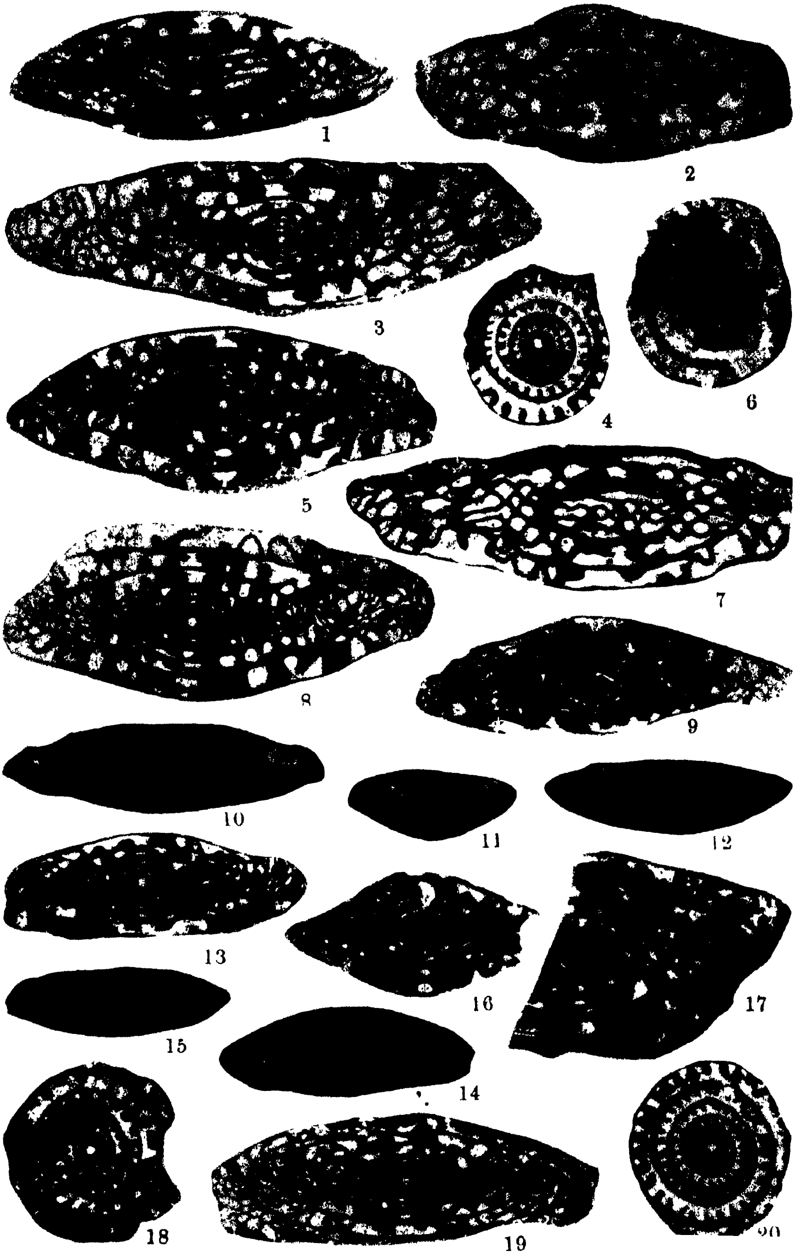
8,11—Axial sections, x20; 18,19—external views, x10; 10—sagittal section, x20.

28-30—*Fusulinella iowensis* Thompson, n. sp. 296

28—Axial section, x20; 29—external view, x10; 30—sagittal section, x20.



Thompson, Des Moines Fusulinids



Thompson, Des Moines Fusulinids

PLATE XXI

All of the specimens illustrated on this plate came from the middle of the Cherokee of Lucas and Monroe counties, Iowa. All illustrations are unretouched photographs.

Page

Figs. 3,7,10,18—*Fusulina leei* Skinner 301

3—Axial section, x20; 7—tangential section, x20; 18—sagittal section, x20; 10—external view, x10.

1,2,4,5,8,12-15,19,20—*Fuslina kayi* Thompson, n. sp. 303

5,8,13,19—Axial sections; x20; 1,2—tangential sections showing septal fluting, x20; 4,20—sagittal sections, x20; 12,14,15—external views, x10.

6,9,11,16,17—*Fusulina? problematica* Thompson, n. sp. 306

16,17—Axial sections showing innermost volutions and proloculum, x20; 19—sagittal section, x20; 20—external view, x10.

PLATE XXII

All of the specimens illustrated on this plate came from the middle and upper portions of the Des Moines series of south-central Iowa. All illustrations are unretouched photographs.

Figs. 2,9,12,17,19—*Fusulina lucasensis* Thompson, n. sp. 309

2,12—Axial sections, x20; 9—sagittal section, x20; 17,19—external views, x10.

4,13,14,18—*Fusulina euryteines* Thompson, n. sp. 310

4,13—Axial sections, x10; 14—sagittal section, x10; 18—external view, x10.

6,8,10,11—*Fusulina pumila* Thompson, n. sp. 313

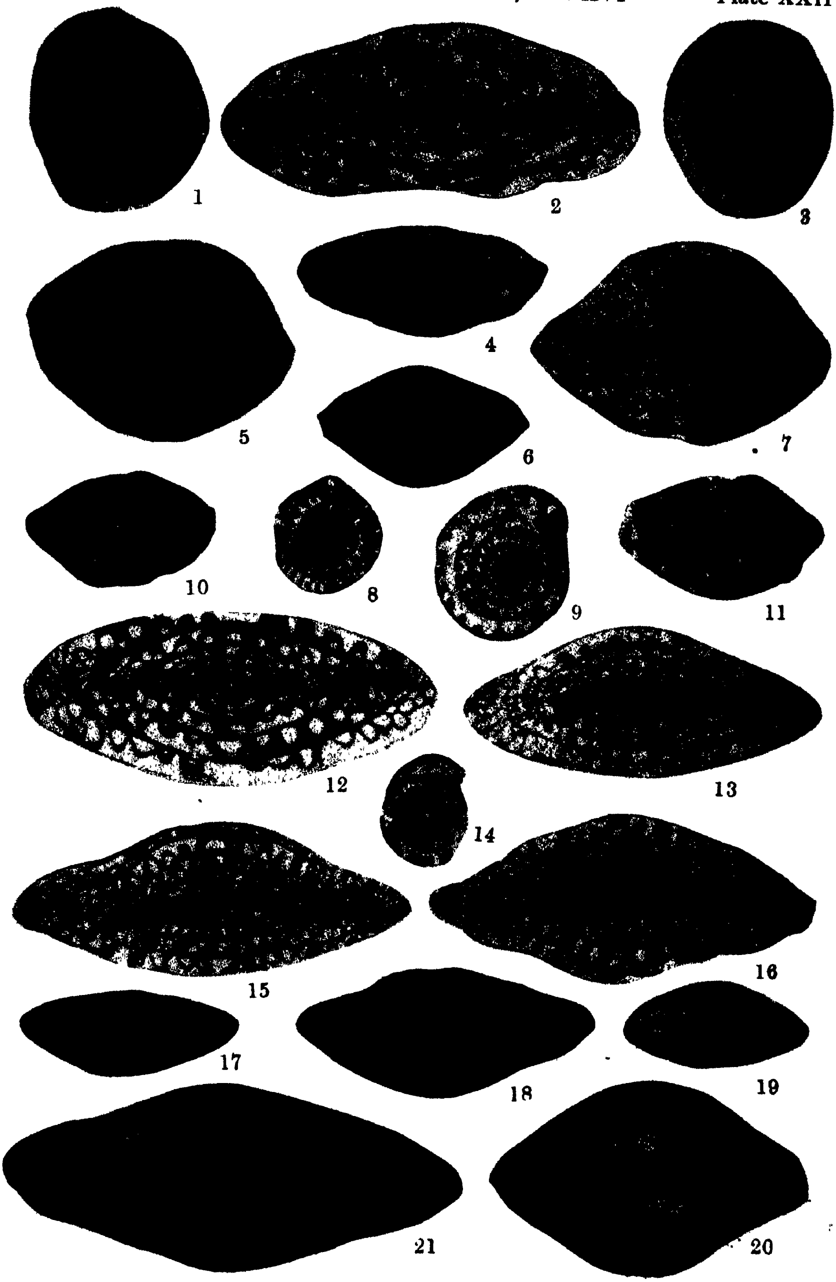
10,11—Axial sections, x10; 8—sagittal section, x10; 6—external view, x10.

1,5,7,20—*Fusulina girtyi* (Dunbar and Condra) 314

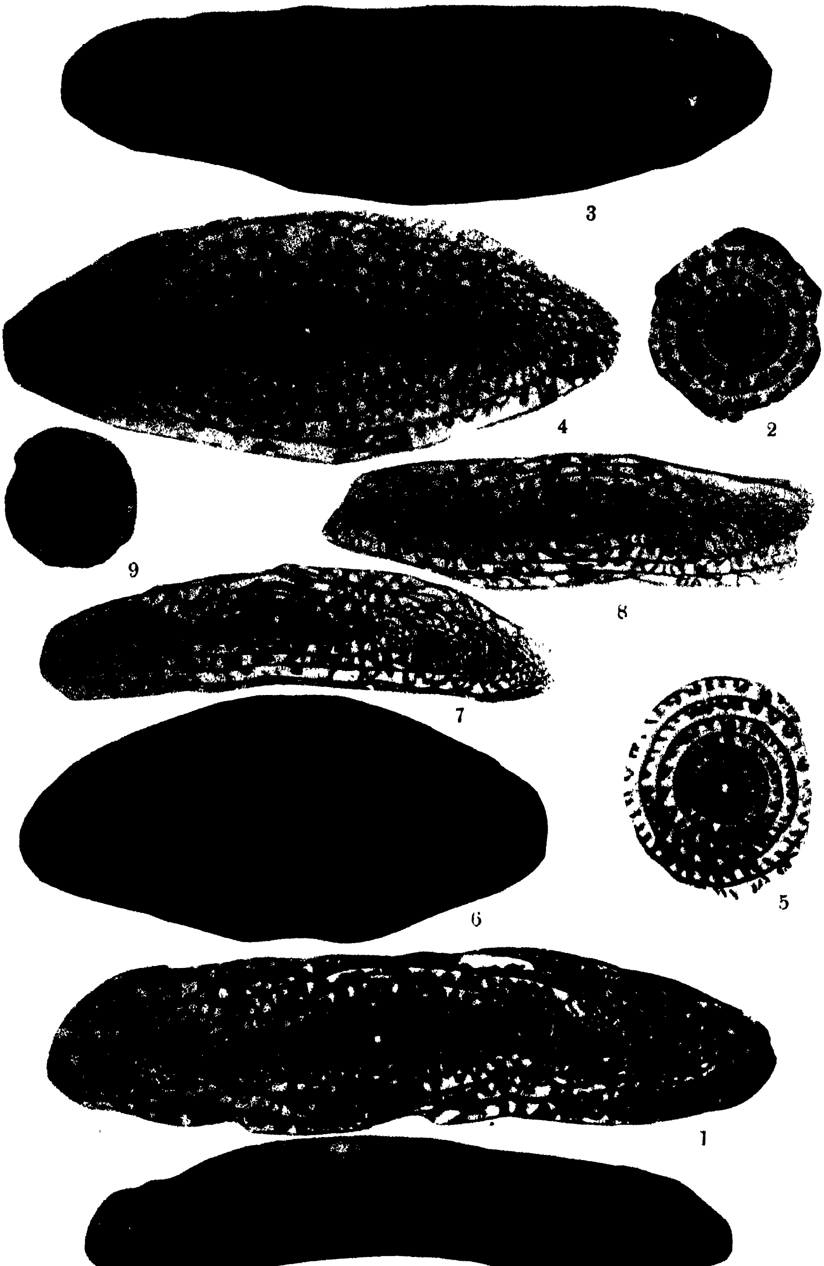
5,7—Axial sections, x10; 1—sagittal section, x10; 20—external view, x10.

3,15,16,21—*Fusulina stookeyi* Thompson, n. sp. 316

15,16—Axial sections, x10; 3—sagittal section, x10; 21—external view, x10.



Thompson, Des Moines Fusulinids



Thompson, Des Moines Fusulinids

PLATE XXIII

All of the specimens illustrated on this plate came from the upper portion of the Des Moines series of south-central Iowa. All illustrations are unretouched photographs.

Page

Figs. 1-3—*Fusulina mysticensis* Thompson, n. sp. 319
1—Axial section, x10; 2—sagittal section, x10; 3—external view, x10.

4-6—*Fusulina megista* Thompson, n. sp. 320
4—Axial section, x10; 5—sagittal section, x10; 6—external view, x10.

7-10—*Fusulina eximia* Thompson, n. sp. 323
7-8—Axial sections, x10; 9—sagittal section, x10; 10—external view, x10.

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Heliantheae of Iowa, III

by

M. Rae Johns

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HELIANTHEAE OF IOWA, III

The two preceding papers on the Heliantheae of Iowa appeared in the Proceedings of the Iowa Academy of Science for 1929 and 1930.

The first series included the genera *Galinsoga, Eclipta, Actinomeris, Parthenium, Polymnia, Ambrosia, Iva* and *Xanthium*—an artificial assemblage of eight small genera grouped for convenience.

In the second series, five conspicuous and well known genera were included, namely: *Heliopsis, Silphium, Rudbeckia, Lepachys* and *Brauneria.* Of these, *Heliopsis* and *Silphium* were shown to have been associated throughout their taxonomic history, and also with them *Galinsoga, Eclipta, Polymnia* and *Parthenium* of Series I, because of their pistillate and fertile ligules. *Rudbeckia, Lepachys* and *Brauneria* were found to form a close natural group, and originally to have been included within the genus *Rudbeckia,* later to be extricated and given equal generic status.

All the genera and species reviewed in these two papers are very distinct, with strong deliminating characters, and so offered little difficulty in identification.

Series III, which includes the three remaining Iowa genera *Helianthus, Coreopsis* and *Bidens,* is here presented and will bring to a close the preliminary survey of the Tribe Heliantheae (Family Compositae) in Iowa.

These three important genera are world-wide in distribution and conspicuous in the flora of all temperate and tropical regions. In Iowa they are well represented by species mostly native to the state, and chiefly of the vigorous and prolific weedy types common to waste places. Their members are also listed among medicinal, economic, and ornamental plants.

They offer difficulties in classification. While they are very distinctive as genera, the species within each genus present many confusing problems of identification. This is because of their ready responses of structure to conditions of environment and also because of probable hybridization in closely related species. Therefore no attempt has been made to place all of the many forms seen in the field nor of plant portions found in herbaria. This would mean

never to complete the survey or to end with a bewildering agglomeration of local environmental forms. As far as possible a positive identification has been made, followed by a carefully worked out description of details, with drawings to aid in recognition of the species. The more striking variations are then given.

It has been left to others of more extensive and world-wide experience in the taxonomic field to create new specific and varietal names for seemingly stable though unnamed forms afield. The way to positive determination of species will be greatly aided by the geneticist who may be able, by the chromosome method, to reveal the true kinship of the "plastic" species of these three genera.

TRIBE HELIANTHEAE

Leaves opposite or alternate, simple or pinnate. Heads radiate or discoid, disk brown or yellow. Disk-flowers perfect and fertile, or sterile. Ray-flowers pistillate and fertile or sterile, or neutral. Receptacle chaffy, flat, or convex to columnar. Involucre of leaf-like green bracts in 2 or more rows. Anthers united, or nearly free, not caudate but mostly entire at base. Style-arms truncate or hairy-appendaged. Akenes flat or angled with margins winged or wingless. Pappus of chaffy scales, 2-4 hard awns, a mere crown, or none.

Key to Genera of Tribe Heliantheae

a. Heads mostly radiate; anthers united . . . . b.
- b. Disk-flowers perfect and fertile; rays neutral or sterile . . . . c.
  - c. Rays, when present, neutral or sterile . . . . d.
    - d. Receptacle flat to low convex; rays neutral, yellow . . . . e.
      - e. Chaff persistent; awns deciduous; rays numerous. *Helianthus*
      - e. Chaff deciduous; awns, if present, persistent; rays 2-8 or none . . . . f.
        - f. Akenes not winged, awns barbed; rays usually 8, absent in some. *Bidens*
        - f. Akenes winged; awns naked or absent; rays 2-8 or absent . . . . g.
          - g. Pappus of 2-3 long smooth awns; bracts distinct; rays 2-8, ephemeral or absent. *Actinomeris**
          - g. Pappus none or 2 small teeth; bracts united at base; rays 8, rarely absent. *Coreopsis*
    - d. Receptacle conical to columnar; rays neutral or sterile . . . . h.
      - h. Akenes flattened, margined; chaff hood-shape; rays yellow, neutral. *Lepachys**
      - h. Akenes thick, not margined, chaff merely concave; rays yellow or light purple, neutral or sterile . . . . i.

* Treated in previous papers.

i. Rays light purple, pistillate and sterile; chaff cuspidate, exceeding disk-flower. *Brauneria**

i. Rays orange-yellow, neutral; chaff rounded or spinose, shorter than disk-flower. *Rudbeckia**

c. Rays pistillate and fertile . . . . j.

j. Pappus of 4-5 fimbriate chaffy scales; rays white *Galinsoga**

j. Pappus a mere toothed border; rays yellow or white . . . . k.

k. Receptacle conical; akenes smooth; rays yellow. *Heliopsis**

k. Receptacle flat; akenes roughened and hairy; rays white. *Eclipta**

b. Disk-flowers sterile; rays pistillate and fertile . . . . l.

l. Conspicuously radiate, rays numerous, yellow; receptacle flattened. *Silphium**

l. Inconspicuously radiate, rays few, white; receptacle flat or conical . . . . m.

m. Akenes flat; pappus of 2 squamellate awns or obsolete; receptacle conical. *Parthenium**

m. Akenes thickened; pappus a slight coriaceous ring or none; receptacle flat. *Polymnia**

a. Heads not radiate; anthers barely united or free in maturity . . . . n.

n. Heads with both staminate and pistillate flowers; the latter few and marginal. *Iva**

n. Heads with either staminate or pistillate flowers; the latter 1-3-∞.

o. Bracts of staminate heads united; fruit nut-like, 1-seeded. *Ambrosia**

o. Bracts of staminate heads distinct; fruit bur-like, 2-seeded. *Xanthium**

Genus Helianthus L.

Spec. Pl. 1 ed. 904. 1753.

Vosacan Adans. Fam. 2:130. 1763.
Harpalium Cass. Bul. Soc. Philom. 141. 1818.
Discomela Rafin. Neogenyt. 3. 1825.
Diomedia Bertol. Mem. Acc. Torin. 38:31. 1835.
Chrysis Renealm. ex. DC. Prodr. 5:585. 1836.
Flourensia DC. Prodr. 5:592. 1836.
Echinomeria Nutt. in Trans. Am. Phil. Soc. 7:356. 1841.
Linsecomia Buckl. in Proc. Acad. Sci. Philad. 458. 1861.

Helianthus, from the Greek ἥλιος, the sun, and ἄνθος, a flower, refers to the large rayed inflorescence of this genus, typified by the sunflower. The genus is believed to have made an early geologic appearance in the lower Pliocene period of the Tertiary Age. Originating in Peru, it is indigenous to the Americas, whence its

members have travelled to all tropical and temperate regions of the world.

There are between fifty-five and sixty species of *Helianthus* in America, twenty-four of which are included in the territory covered by Gray's Manual, 7th Edition. In Iowa, the genus is represented by the following known species: *H. annuus* L., *H. petiolaris* Nutt., *H. scaberrimus* Ell., *H. grosseserratus* Martens, *H. giganteus* L., *H. Maximiliani* Schrad., *H. hirsutus* Raf., *H. divaricatus* L., *H. strumosus* L., *H. decapetalus* L., *H. laetiflorus* Pers., *H. occidentalis* Ridd., *H. mollis* Lam., *H. tuberosus* L. and *H. tracheliifolius* Mill. Three additional species have been reported: *H. tomentosus* Michx., *H. doronicoides* Lam. and *H. atrorubens* L., but it has been shown that they are limited to areas in which Iowa is not included.

The species of this genus are large, coarse, annual or perennial herbs, with some woody forms found in the tropics. They inhabit various diversified regions which range from the very moist to the driest areas and they respond to these local conditions by presenting variability of form and by developing such protective structures as harsh strumose surfaces, hairy screens, resin, and extensive, sometimes thickened, root-systems.

They fall into such natural groups that while the extreme types are readily recognized, the hybrids may so conform to either or both parent species as to make classification difficult and doubtful. To this intermingling of related species, add the structural responses to environment, the meager content of early descriptions by the discoverers of the species, the incomplete herbarium material, usually only the upper part of the specimen being preserved, and we have the combined conditions which will continue to cause confusion in this strong genus. It is certain that there are and always will be plants of this genus that cannot be positively placed.

Helianthus is distinguished as a genus by the following typical structures:

Stem: erect and branching, herbaceous.

Leaves: simple, opposite or alternate or both, usually 3-nerved, narrowed upon the petiole or petiole distinct, surface strumose, margins serrate to entire, linear-lanceolate to broad ovate or cordate.

Heads: many flowered, radiate, receptacle chaffy, flat to low convex.

Involucre: hemispheric to depressed, bracts in 2 or 3 series, leaf-

like and green, erect, appressed, squarrose or reflexed, glabrous, ciliate, or hispid.

Ray-flowers: numerous, yellow, neutral.

Disk-flowers: numerous, tubular, 5-lobed, tubes short, lobes brown-purple or yellow, perfect and fertile.

Chaff: entire or tricuspidate, subtending disk-flowers, persistent.

Akene: dark, thick or compressed, angled, summit truncate to rounded, glabrous or nearly so.

Pappus: 2 very deciduous scales or awns, often 2 or more small additional ones.

Underground parts: root annual or perennial, fibrous; axillary buds, crown buds, rhizomes, tubers in a few.

Distinction among the species is based upon the general nature of the surfaces, the branching of the stem, the arrangement, venation, surfaces and margins of the leaves, the position, length and surface of the involucral bracts, the length, shape and pubescence of the chaff, the color, shape, and pubescence of the disk-flowers, the number, color and shape of the rays, the shape of the akene and the awns, and the kind and formations of the root system.

The nearest allies to the genus *Helianthus* L. are *Flourensia* DC., shrubs with obsolete or narrow and acute squamellae and akenes densely villous, and *Viguicra* HBK., herbs with short rounded fimbriate squamellae and akenes very pubescent. In *Helianthus* the receptacle is always chaffy and the akene is nearly if not quite glabrous.

Key to Species of Genus Helianthus

a. Receptacle flat; leaves alternate; disk brown; 2-4 cm. broad; annuals . . . . b.
  b. Leaves gray-green, oblong to deltoid-lanceolate; innermost chaff white-bearded. *H. petiolaris*
  b. Leaves not gray-green, ovate to cordate; chaff not bearded. *H. annuus*

a. Receptacle convex; leaves alternate or opposite; disk brown or yellow, 1-2.5 cm. broad; perennials . . . . c.
  c. Bracts appressed, not exceeding disk; disk brown or yellow . . . . d.
    d. Disk brown, bracts closely appressed, obtuse or acute, shorter than disk . . . . e.
      e. Stem stout, rough, hispid with short hairs; leaves very thick and rigid, scabrous-hispid on both sides. *H. scaberrimus*
      e. Stem slender, hairy with long white hairs; leaves thinnish but very coarse, hirsute on both sides. *H. atrorubens*

d. Disk yellow; bracts not so appressed, acute to acuminate, equalling disk . . . . f.
  f. Stem stout, leafy throughout; leaves narrowed into short petioles; heads corymbed, disk 1.5 cm. broad. *H. laetiflorus*
  f. Stem very slender, naked above; leaves mostly near base of stem, narrowed into long margined petioles; heads solitary or few, disk 1 cm. broad. *H. occidentalis*

c. Bracts loose, equalling or exceeding disk; disk yellow . . . . g.
  g. Leaves mostly alternate throughout . . . . h.
    h. Leaves broad lance-oblong, 3-nerved; bracts very long, hairy, squarrose or reflexed; disk 2.5 cm. broad. *H. tomentosus*
    h. Leaves narrow, not 3-nerved, bracts spreading, not reflexed; heads smaller . . . . i.
      i. Stem smooth and glaucous; leaves coarsely serrate, white-pubescent below. *H. grosseserratus*
      i. Stem scabrous and hispid; leaves scabrous on both sides . . . . j.
        j. Stem gray appressed-hispidulous; leaves gray-canescent both sides, falcate and conduplicate. *H. Maximiliani*
        j. Stem not gray hispid; leaves green both sides, not falcate nor conduplicate. *H. giganteus*
  g. Leaves opposite at least to inflorescence . . . . k.
    k. Leaves sessile or subsessile . . . . l.
      l. Leaves 3-nerved from the middle, narrowed to base of petiole; bracts long attenuate, reflexed. *H. doronicoides*
      l. Leaves 3-nerved from broad base; bracts shorter, not reflexed . . . . m.
        m. Stem stout, villous to hirsute and hispid; leaves ascending, with broad clasping bases, soft gray-canescent both sides. *H. mollis*
        m. Stem slender, mostly glabrous and glaucous, slightly hispid above; leaves divaricate, sessile or very short petioled; green both sides. *H. divaricatus*
    k. Leaves distinctly petioled . . . . n.
      n. Leaves short petioled . . . . o.
        o. Leaves thickish and firm, lighter beneath, narrowed to short margined petioles; bracts equalling disk . . . . p.
          p. Leaves hirsute-pubescent beneath; stem stout, bristly hairy; bracts recurved. *H. hirsutus*
          p. Leaves whitish and softly pubescent beneath; stem smooth and glaucous, or sparsely hispid above; bracts with tips merely squarrose. *H. strumosus*
        o. Leaves thinner, nearly equally green both sides, the petioles not margined; bracts attenuate, much exceeding disk. *H. tracheliifolius*
      n. Leaves longer petioled . . . . q.
        q. Stem mostly smooth, slightly hispid above; bracts at-

tenuate, often much exceeding disk, spreading; rhizomes not tuber bearing. *H. decapetalus*

q. Stem scabrous and hispid; bracts not much exceeding disk, squarrose; rhizomes tuber bearing. *H. tuberosus*

HELIANTHUS ANNUUS L.
Sp. pl. 904. 1753.

Helianthus indicus L. Mant. 1:114. 1761.
Helianthus tubaeformis Nutt. Gen. N. Am. 2:177. 1818.
Helianthus platycephalus Cass. Dict. Sci. Nat. 22:352. 1821.
Helianthus macrocarpus DC. Pl. Rar. Jard. Gen. Ume. Nob. 8. 1826.
Helianthus ovatus Lehm. Ind. Sem. Hort. Hamb. 16. 1828.
Helianthus lenticularis Dougl. Bot. Reg., 1265. 1829.
Helianthus grandiflorus Wender ex. Steud. Nom. 2 ed. 737. 1841.
Helianthus aridus Rydberg, Bull. Torr. Bot. Club 32:127. 1905.

Stem: 1-4 m. tall, simple but often branched above, hispid or scabrous, often purple spotted above.

Leaves: alternate except the lowest, broadly ovate, the lower cordate, obtuse to acute, 3-nerved at base, somewhat narrowed on petiole, petiole sometimes long; dentate, finely serrate to nearly entire, coarse in texture, rough both sides, not thick, strigose-hispid, scabrous above, hispid or sometimes pubescent below, 1-3 dm. long, larger in cultivation.

Heads: solitary, in that case larger, or several smaller heads from upper axils on long stout rough peduncles, disk brown, 3-4 cm. in diameter, receptacle flat.

Involucre: flat or depressed, bracts ovate or oblong, long acuminate or aristate, hispid-ciliate, equal to the disk, sometimes longer.

Ray-flowers: numerous, bright yellow.

Disk-flowers: lobes dark brown-purple, yellow below, tube short, bulbous base of limb pubescent.

Chaff: large, oblong, acuminate, with 2 short and narrowly acute lateral cusps, purplish and pubescent at tips.

Akenes: large, oblong to obovate, striate, mostly glabrous, or slightly pubescent at summit, varied mottled to dark brown.

Pappus: 2 broadly lanceolate awns 1/3 length of the disk-flower.

Root: annual, fibrous.

Helianthus annuus is best known in its cultivated forms of which there is an increasing number of varieties, some with yellow disks and brownish-red rays. The large head atop the simple, tall, stout stem is its most outstanding feature. The "Wild Prairie Sunflower," as it is called, differs from the cultivated form in being

smaller, profusely branched, with numerous smaller heads and smaller leaves; the disk is always brown. All forms, wild and cultivated, are regarded as environmental varieties of the one species *H. annuus* L.

Variations are extremely numerous in all the grosser parts of the plant, all affected by surrounding conditions. It thrives best in rich soil, growing large and luxuriant, but it is found in all types of habitats, in poor soils responding by reduction of parts and increased harshness of surface. It blooms from July through the late summer and fall until frost.

It is said to be a native of the warmer parts of America, Peru and Mexico being given as its original home (Gray's Manual, 7th edition). The wild sunflower of the California plains probably is the ancestral type of the cultivated form. It early attained a wide distribution throughout America from California to British America because of its extensive use by the Indians. Champlain (1615) and Kahl (1794) and others saw it grown by them for food and for other uses. Today, in other parts of the world, it is used even more extensively. "In Russia, the seeds are ground into meal for tea-cakes, and the whole seeds roasted and used as coffee substitute, the oil is expressed into oil-cake for cattle food. The buds before they be flowered are boiled and eaten with butter, vinegar and pepper as artichokes and make an exceeding pleasant meat. In Germany the dried leaves are used for tobacco, the seed receptacle made into blotting paper, and the inner part into fine writing paper. The stalks yield a silky fiber of excellent quality, and the green leaves make good fodder."[1]

In Iowa, the escaped form is abundant, ranking as a troublesome weed, but the wild form also is frequent in waste places along roadsides and on prairies. It is reported from all parts of the state but seems to be more abundant in the western part.

HELIANTHUS PETIOLARIS Nutt.

Journ. Acad. Phila. 2:115. 1821.

Helianthus patens Lehm. Ind. Sem. Hort. Hamb. 8. 1828.
Helianthus integrifolius Nutt. in Trans. Am. Phil. Soc. 7:336. 1841.
Helianthus aridus Rydb. Bull. Torr. Club 32:127. 1905.

Plate XXIV

Stem: 0.3-2 m. tall or more, simple or more usually much branched and bushy from the base, very rough and hispid, stout.

[1] See Sturdevant's Notes on edible plants. Rept. N. Y. Agri. Exp. Sta. 2, pt. 2:289. 1919.

Leaves: alternate above the lower part, variable, 3-9 cm. long, oblong-lanceolate to ovate or deltoid-lanceolate, acute, narrowly or broadly cuneate or the lower sometimes nearly cordate at the base, 3-nerved, the lateral nerves converging at the base of the blade, petioles varying in length but mostly as long or longer than the blade, the lowest leaves deeply dentate or serrate-dentate, the upper shallowly toothed or merely undulate, scabrous-hispid, more so below, grayish-green in appearance.

Heads: large and showy, 7-10 cm. broad, solitary or paniculate, terminal on main stem and upper branches, peduncles long, disk dark brown 1.5-3 cm. broad.

Involucre: bracts erect, lanceolate or oblong-lanceolate, acuminate, subulate-tipped, 8-12 mm. long, about as long as disk or a little longer, scabrous, hoary-canescent, densely hispidulus, ciliate or not.

Ray-flowers: 12-20, bright yellow, oval, about 2.5 cm. long.

Disk-flowers: 5 mm. long, slender, red or purple-brown lobes pubescent, bulbous base and short tube densely pubescent.

Chaff: large, 3-cuspidate, lateral cusps short and distant, middle cusp acute or short acuminate with purplish mucronate tip, hispid, inner ones bearded with conspicuous dense white hispidity.

Akenes: brown, 5 mm. long, oblong, thickish, rounded to truncate at summit, densely villose when young, evenly villous when mature.

Pappus: 2 lanceolate chaffy awns one half as long as the disk corollas.

Underground parts: root annual, with many fibrous branches.

This species is a close relative of *H. annuus* which it resembles in its more vigorous forms. Its identity, however, is maintained in its generally smaller size, more bushy contour, and gray-green aspect. The long-petioled arrow-shaped leaves, the conspicuous beard-like hispidity of the inner chaff, and the smaller though none-the-less handsome heads with short lighter-yellow rays also distinguish it from *H. annuus*.

It, too, is called the "Prairie Sunflower", because of its frequent appearance in prairie regions, sterile hillsides, and other arid places. The heads appear throughout August and September.

Its range is from Saskatchewan to Minnesota, Missouri, Nebraska,

Arizona, and Texas, west to Oregon, rarely naturalized eastward. Naturalized in Iowa from the western states, it is now rather common locally along roadsides, railroad beds, in arid soil along streams and in sand and gravel areas. Abundant material was collected from such areas by the writer. A luxuriant growth of these sturdy sunflowers was seen near Fruitland, Iowa, where a patch several rods wide adorned the roadsides and fields on both sides for more than a mile, excluding nearly all other vegetation.

Herbarium specimens were from the counties of Appanoose, Delaware, Iowa, Lee, Louisa, Mahaska, Union, Muscatine, and Woodbury. It is reported from the following counties: Dubuque (11), Hardin (40), Johnson (56), Linn (60), Louisa (4), Muscatine (12), Scott (4) and from the state of Iowa (17, 37).

HELIANTHUS SCABERRIMUS Ell.

Sketch. 2:423. 1824.

Helianthus rigidus (Cass.) Desf. Cat. Hort. Paris Ed. 2:184. 1829.

Plate XXV

Stem: 0.5-2 m. tall, stout, simple or sparingly branched above, rigid, scabrous, hispid with short stiff antrorse hairs from papillae, often smoother and purplish above, exudes resin in small amount.

Leaves: mostly opposite, or uppermost alternate, oval to linear-lanceolate or elliptic-lanceolate, obtuse to acute, strongly triple-nerved above the base, and narrowed to base of petiole, lowest somewhat petioled, shallowly serrate or nearly entire, upper leaves lanceolate or elliptic-lanceolate, acute, or acuminate at each end, subsessile, somewhat triple-nerved, all extremely thick, rigid and coriaceous, scabrous both sides, hispid with short antrorse bristles from papillae, often with ''whitish blistered appearance.''

Heads: solitary or few on long, slender, nearly naked, purple-red peduncles, disk brown-purple, 2-3 cm. broad, receptable convex.

Involucre: high convex; bracts dark green, ovate, obtuse or acute, shorter than the disk, erect, closely appressed and imbricated in 3-4 rows, at base striate, shiny and somewhat sticky, evenly ciliate on margins to apex.

Ray-flowers: 15-25, orange-yellow, erect-divergent, 2.5-4 cm. long, mostly 2-toothed.

Disk-flowers: 1 cm. long, lobes mostly purple-brown, tube short and glabrous, the limb very pubescent on bulbous base, very slightly so on veins and lobes.

Chaff: almost as long as disk-flowers, dark at apex, obtuse, entire or with lateral cusps very small and short, ciliate on keel and apex.

Akenes: dark, oblong, thick, pubescent throughout when young, only so at the rounded summit when mature.

Pappus: 2 large broad-lanceolate concave scales rather than awns, often with small intermediate ones.

Underground parts: root perennial; rhizomes thick.

H. rigidus (Cass.) Desf. is the name which properly designates this species. *H. scaberrimus* of Elliott is known to have had the disk-flowers yellow and therefore could not have been this dark centered form. Since Gray's Manual, 7th edition, recognizes *H. scaberrimus* Ell., giving *H. rigidus* (Cass.) Desf. as a synonym, such usage is followed in this treatment.

This stout coarse species, called the "Stiff Sunflower", is easily recognized by the extremely harsh surfaces, the mostly opposite, ascending, thick, rigid, and scabrous leaves, and the brilliant dark centered heads on long slender, hirsute, reddish peduncles. It is distinguished from *H. laetiflorus* Pers. by the generally harsher surfaces, the erect, appressed, acute, shiny, ciliate bracts and the red-purple lobes of the disk corollas.

Unlimited variation is shown in the form and harshness of the leaves. A plant in the Missouri Botanical Garden herbarium was far less harsh and scabrous than the prairie individuals. Ternate-leaved forms are occasionally found.

It is common on prairies, in fields along fences and roadsides. It comes into bloom late in July, lasting through August to the middle of September.

In North America, its range is from Saskatchewan to the Rocky Mountains, to Illinois, Minnesota, Michigan, Dakota, eastern Colorado, south to Georgia and Texas. In Iowa it is common to abundant on dry ridges, roadsides and edges of fields, also in sand and gravel areas. Abundant material was secured in such localities visited. A dark green, extremely harsh plant with ternate leaves throughout was found along the railroad between Wilton and Summit, and also one on the dry ridge of a large kettle-hole in the region of Lake West Okoboji. Strong vigorous plants were found

holding their own along with other dry prairie forms, on the sand dune areas near Muscatine. Herbarium specimens are abundant. It is reported in all local, county and state lists.

HELIANTHUS LAETIFLORUS Pers.

Syn. 2:476. 1807.

Helianthus atrorubens Lam. Encyc. 3:86. 1789.
Helianthus tricuspus Ell. Sketch 2:422. 1824.

Plate XXVI

Stem: 1-1.5 m. or more tall, simple or somewhat trichotomously branched above, scabrous and reddish-purple as in *H. scaberrimus* Ell., hispid with hairs spreading, leafy throughout.

Leaves: opposite or uppermost alternate, base of petioles approximate, broadly lanceolate, acuminate, contracted at base into short petioles, or narrowed on petiole, triple-nerved, near base the veins anastomosing with these lateral nerves, serrate, very scabrous both sides, hispid-pubescent beneath, coriaceous, less thick and harsh than *H. scaberrimus*.

Heads: solitary or several on long hispid peduncles, somewhat corymbose, disk yellow.

Involucre: campanulate-cylindrical, bracts in 3 series, ovate to broad linear-lanceolate, acuminate, about as long as the disk, slightly pubescent on back or nearly smooth, cilia on margins longer toward base, not so appressed as in *H. scaberrimus*, ribbed at base.

Ray-flowers: 12-20, 2 to nearly 5 cm. long, deep yellow.

Disk-flowers: yellow, lobes rarely tinged with purple, villous-pubescent at bulbous base, tube short, glabrous.

Chaff: long, entire and acute or with 2 distant and small lateral cusps, hirsute-pubescent and purplish at apex and along keel.

Akene: somewhat compressed, entirely pubescent when young, only at the summit when mature.

Pappus: 2 subulate pubescent awns dilated at base, with one or two smaller squamellae on each side.

Underground parts: root perennial, of coarse fibers; rhizomes slender, occasionally with tubers.

This brilliant sunflower becomes very luxuriant in cultivation with longer, broader leaves and larger, more numerous heads. The whole plant is stout and coarse but showy. It grows in dry open

places, along roadsides and edges of woods. In the field it resembles *H. scaberrimus* (*H. rigidus Desf.*), and often is found near it, even co-mingled with it. Its more leafy aspect, the less scabrous nature of the stem and leaves, and the yellow flowers of the disk, distinguish it. Also the involucral bracts are more acute and not so appressed, and the leaf serratures are more constant than in *H. scaberrimus.*

Its range in America covers almost the same territory as *H. scaberrimus,* namely: Ontario to Georgia, Indiana, Illinois, Wisconsin, Minnesota, Dakota, Nebraska, Arkansas and Texas. In Iowa, it is frequent to common on prairies, roadsides and other dry places. The writer secured plants in flower and fruit by the interurban track near Iowa City, in isolated groups along roadsides east of Davenport, and also in cultivation in the city of Davenport. No doubt, it is often overlooked as a species, or in the vegetative phase classed as one of the many forms of its dark-centered neighbor.

Herbarium specimens were from the counties of Clinton, Sac, Hardin, Cerro Gordo, Fayette, Floyd, Clay, Lyon, Decatur, Emmett, Chickasaw, Cherokee, Winnebago, Kossuth, Jasper and Palo Alto. The lists for Iowa report it from the following counties: Fayette (10, 12), Iowa (51), Jackson (12, 42), Johnson (12, 42), Mitchell (59), Muscatine (4, 12), Story (12, 20) and from the state of Iowa (1, 17).

HELIANTHUS OCCIDENTALIS Ridd.

Suppl. Cat. Ohio, Pl. 13. 1836.

Helianthus heterophyllus Nutt. Journ. Acad. Phila. 7:74. 1834.
Helianthus illinoensis Gleason, Ohio Nat. 5:214. 1904.
Helianthus occidentalis var. *illinoensis* (Gleason) Gates, Bull. Torr. Club. 37:79. 1910.

Plate XXVII

Stem: 0.5-1 m. tall, erect, slender, usually simple or sparingly branched above, scabrous, somewhat hispid especially below, nearly leafless above, pale green, somewhat reddish.

Leaves: few, opposite, mostly near the base on the first few nodes, oblong-elliptic to ovate-lanceolate, 3-nerved, narrowed into long margined, ciliate petioles, approximate at base, obtuse or acutish, obscurely serrate to nearly entire, scabrous-hispid above, roughish-pubescent to hirsute beneath, upper leaves remote and bract-like.

Heads: small to medium, solitary or several on long slender reddish hispid peduncles, disk 1 cm. broad, yellow.

Involucre: bracts ovate-lanceolate, or lanceolate, acuminate, scarcely as long as the disk, loose, subpubescent or nearly glabrous, margins longer ciliate toward base.

Ray-flowers: 11-17, bright yellow, 1-2 cm. long, acute or 2-toothed.

Disk-flowers: yellow, 4 mm. long, lobes spreading and glabrous, limb cylindrical, fine-pubescent below, and on very short tube.

Chaff: nearly as long as the disk-flower, acute, somewhat 3-cuspidate, slightly pubescent at apex.

Akene: brown, angled, truncate, pubescent toward summit and very much so along the two main angles when young.

Pappus: 2 lanceolate subulate awns, occasionally with 2 shorter ones.

Underground parts: root perennial.

This dainty ''Few-leaved Sunflower'' is a very distinct species, easily recognized in the field by its slender reddish wand-like and nearly leafless stem, and the small bright yellow heads on long peduncles. Variations are found in the height of the stem and the extent of its pubescence, the distribution of the leaves upon the stem, and the infinite variety of their form, size, and the length of the petiole. Plants observed growing in rich moist soil in Missouri Botanical Garden were only slighty scabrous and the leaves were much larger than any found on plants in the field.

The variety *Dowellianus* (Curtis) T. & G., reported for Illinois, differs from the species in being taller, more robust, more branched and leafy above, merely appressed-pubescent, the leaves larger and broader, and the heads more numerous.

These plants are typical of the prairie, dry soil of barrens, and sand areas. They bloom through August and September.

In the United States, *H. occidentalis* has become established in the District of Columbia and on the New Jersey Coast; it is distributed from Michigan, Minnesota, Ohio, southwest to Missouri, Kentucky, Florida, and Texas. In Iowa it is frequent to common in the eastern part in dry open places, sandy copses and in pure sand and gravel areas, the patches often widely separated. Large colonies of this attractive little sunflower were encountered by the writer at Cou Falls and along the interurban track near Iowa City; specimens were gathered from isolated groups along a railroad track southeast of Iowa City; scattered individuals were found dotting a sandy field and wayside in the vicinity of the sand mounds in

Muscatine County; a small plant bearing a solitary head was found on the hard dusty roadside near McCausland. Herbarium specimens were from the counties of Lee, Fayette, Allamakee, Clayton, Delaware, Muscatine, and Winneshiek. It is reported from the following counties: Benton (12), Clinton (12), Emmett (30), Fayette (10, 12, 15), Henry (12, 49), Johnson (11, 12, 49, 56), Lee (12), Linn (53), Lyon (45), Muscatine (4, 12, 49), Scott (4, 26), Winneshiek (11) and from the state of Iowa (9, 17, 52).

HELIANTHUS MOLLIS Lam.

Encyl. 3:85. 1789.

Helianthus pubescens Vahl. Sym. Bot. 2:92. 1794.
Helianthus canescens Michx. Fl. Bor. Am. 2:140. 1803.

Plate XXVIII

Stem: 0.5-1 m. tall, simple, often tufted, with erect or ascending branches, very stiff and firm, when young villous throughout, in age often hirsute and hispid, somewhat smoother below, leafy throughout.

Leaves: opposite, or the upper alternate, ascending, ovate to ovate-lanceolate, 5-15 cm. long, with a broad, sessile, somewhat cordate clasping base, acute, nearly entire or serrate-crenate with small teeth, both surfaces canescent, the upper slightly scabrous, the lower very soft and velvety, grayish-green, 3-nerved above the base.

Heads: solitary or few, racemose on short stout peduncles, showy, 5-7 cm. broad, disk about 2 cm. wide, yellow.

Involucre: hemispheric, bracts oblong-lanceolate, or with lanceolate tips, 1-1.5 cm. long, bristly villous-canescent, the outer somewhat unequal, erect to squarrose, about equalling the disk.

Ray-flowers: 15-21, bright yellow, 2-3 cm. long, pubescent at base and along veins on under side.

Disk-flowers: yellow, tube short, limb cylindrical, base and corolla lobes canescent.

Chaff: 9 mm. long, linear, almost entire or rarely 2 small lateral cusps, canescent at the summit and on the keel.

Akene: pubescent at summit when young, nearly glabrous when mature.

Pappus: 2 lanceolate, chaffy, fringy awns.

Underground parts: root perennial, with many fine rootlets;

rhizomes short, thick; crown buds at base of stem late in the season.

This strikingly handsome sunflower is easily recognized by its extreme canescent gray-green appearance, the sessile, clasping leaves, especially the tufted ascending branches and the large erect showy heads on short stout, stiff peduncles. From this canescent form, it grades into less woolly, greener and even scabrous variants which approach its near relatives *H. doronicoides* Lam. and *H. tomentosus* Michx.

In the wild, it thrives in dry wooded areas and in open barren ground. It responds to cultivation, but becomes coarse and weedy and not so desirable. The blossoms appear throughout August and September.

Its range in the United States is from New York to Ohio, Indiana, Kansas, Missouri, south to Georgia and Texas. Specimens were examined from Shaw's Gardens, St. Louis. Herbarium specimens were from Muscatine and near Duck Creek, Davenport. Father Hauber loaned good herbarium specimens from the St. Ambrose College grounds. In August, 1933, a thriving group of this species was discovered among the sumac at the roadside in Duck Creek Park, Davenport. Here, late in the fall, the writer secured several specimens, each with two or three dark red crown-buds. In 1934, only a few plants of this species were to be found at this spot, probably due to the dry summer of that year.

It is reported as belonging to the flora of Iowa by J. C. Arthur (1), and T. J. Fitzpatrick (12), from Johnson County by M. P. Somes (56), and from Linn County by E. D. Verink (60).

HELIANTHUS GROSSESERRATUS Martens

Sel. Sem. Hort. Lov. ex. Linnaea 14. Litt. 133. 1840.

Stem: 1-3 or 4 m. tall, simple, branched above, very smooth, sulcate, almost always purplish and with whitish bloom, the upper branches strigose-pubescent, leafy throughout.

Leaves: opposite below, alternate above, or sometimes opposite throughout, lanceolate or oblong-lanceolate, long acuminate, sharply and coarsely serrate or sometimes saliently so, the uppermost denticulate or nearly entire, mostly obtuse at the base, slender and short-petiolate, slightly though not noticeably triple-nerved, thinnish, scabrous above, tomentose-canescent be-

neath; large leaves may be 1-2 dm. or more long with petioles 2.5-5 cm. long, narrowed about ½ way to base of petiole.

Heads: few to numerous, racemose, cymose or panicled on short slender scabrous-villous peduncles, showy, the disk yellow, 1.5-2 cm. broad, receptacle convex.

Involucre: hemispheric, bracts subulate-lanceolate or oblong, or cuneate with lanceolate tip, loose-attenuate, longer than the disk, unequal, mostly glabrous, somewhat ciliate toward base and tip.

Ray-flowers: 10-20, bright yellow, 2-4 cm. long, apex acute, oblong, concave.

Disk-flowers: 4 mm. long, yellow, slender with short tube and bulbous base, lobes mostly glabrous, base pubescent.

Chaff: linear-oblong, acute, entire or barely 3-cuspidate, dark green and pubescent at the summit.

Akene: brown, oblong or narrower, nearly glabrous, striate.

Pappus: 2 short lanceolate awns.

Underground parts: root, perennial, with fine rootlets; rhizomes many, long, branched.

A typical form of this species is easily recognized by the tall very smooth stem, purplish and with whitish bloom, the strigose-pubescent upper branches, leafy throughout, the coarsely serrate lower leaves whitish canescent below, the smooth loosely attenuate bracts of the involucre, and the dark brown glabrous akene. Variations in size are very great, plants sometimes becoming gigantic and the stem stout and woody. A plant found by the roadside in Muscatine County stood over twelve feet tall, with the lower leaves a foot long. Other variations are found in the leaf arrangement and serratures of the margins. The heads vary in size and are often numerous and luxuriant. The smaller leaved forms seem to approach *H. giganteus* L. but they are distinguished from it by the smooth glaucous stem and canescent under surface of the leaf. It is also closely related to *H. Maximiliani* Schrad., but it does not have the rough hispid stem and alternate leaves with serrulate or entire margins and the frequent conduplicate habit which readily distinguish the latter species.

Helianthus grosseserratus grows in dry soil of plains and prairies, along streams, becoming most luxuriant in low moist places. It begins to bloom in August reaching its maturer stages in September.

It is widely distributed over the United States from Long Island

and Maine west to Ohio, Minnesota, Dakota, Colorado, south to Missouri, western Louisiana and Texas. In Iowa it is so abundant and prolific in low grounds, uncultivated fields, and open wooded tracts that it is listed among the troublesome weeds.

It is included in all local, county, and state lists.

HELIANTHUS GIGANTEUS L.

Sp. pl. 905. 1753.

Helianthus altissimus L. sp. pl. ed. 2:1278. 1762.
Helianthus gigas Michx. Fl. N. Am. 2:141. 1803.
Helianthus virgatus Lam. Encycl. 3:85. 1829.
Helianthus crinitus Steud. Nomen. 2 ed. 1:737. 1841.
Helianthus tuberosus Parry, Owen, Rep. Minn. Surv. 615. 1849.

Plate XXIX

Stem: 1-3 m. tall, simple, rather stout, scabrous, hispidulous above, sometimes glabrous below, often purplish, branched only above.

Leaves: alternate, or opposite below, or scattered, lanceolate to linear-lanceolate or oblong, 10-20 cm. long, acuminate, serrate, dentate, or nearly entire, slightly 3-nerved at base, narrowed into subsessile somewhat ciliate bases, dark green both sides, more scabrous above, pilose-scabrous below, the pubescence not dense but of scattered spreading hairs, more pronounced on the veins.

Heads: showy, 1-2 cm. broad, somewhat corymbose-paniculate, disk yellow, receptacle slightly convex.

Involucre: hemispheric, bracts lanceolate, or elliptic-lanceolate, 8-13 mm. long, acuminate, longer than the disk, hairy or strongly spreading villous-ciliate on the margins, loose-attenuate or squarrose.

Ray-flowers: 10-20, light yellow, 1-2 cm. long, oval.

Disk-flowers: 5 mm. long, yellow, tube short, slightly pubescent at base and on lobes.

Chaff: 7 mm. long, oblong, entire or slightly 3-cuspidate, acute, pubescent at apex and along the keel.

Akene: about 5 mm. long, cuneate-oblong, glabrous.

Pappus: 2 short, lanceolate-subulate awns or scales, slightly fringed or chaffy.

Underground parts: root perennial; crown buds; often short fleshy edible tubers.

This species approaches *H. grosseserratus* Martens, but it does

not grow so large and differs otherwise in being rather stout, scabrous or hispidulous, the leaves mostly alternate or scattered, not canescent below, opposite only in unfavorable habitats, the bases 3-nerved, subsessile, and ciliate.

It has a more limited habitat than *H. grosseserratus,* being strictly a species of low ground such as swamps, borders of marshes, wet meadows, low thickets and copses. It blossoms through August and September.

In North America, this species is distributed from Ontario to Manitoba and the regions of the Rockies; eastward, it is found in Maine, New York, New Jersey, Virginia; southward it is said to be found in Louisiana and Texas, although by some it is claimed not to exist south of the Missouri line. In Iowa, it is rare to frequent in open woodlands, borders of marshes, and other moist ground.

The verified specimens examined were from Missouri Botanical Garden. Iowa specimens in the herbaria were from Allamakee, Hamilton, and Muscatine Counties.

It is reported, somewhat doubtfully, from counties as follows: Fayette (10, 14, 15), Linn (60), Muscatine (4), Scott (4), Story (23) and from the state of Iowa (12, 17).

HELIANTHUS MAXIMILIANI Schrad.

Ind. Sem. Hort. Götting. 1835.

Helianthus subtuberosus Bourg. ex. Gray Syn. Fl. N. Am. 1803.

Plate XXX

Stem: 1-3 m. tall, stout, usually branching above, often simple, sometimes tufted, branches ascending, leafy throughout, internodes short, appressed scabrous-hispidulous, somewhat smooth toward base.

Leaves: mostly alternate, sometimes opposite in reduced forms, lanceolate, linear, or oblong-lanceolate, 10-15 cm. long, 1-2 cm. broad, acuminate at both ends, the lower leaves narrowed to the base of petiole, upper leaves with narrowed sessile bases, entire or denticulate, not noticeably 3-nerved, very scabrous and often canescent and strigose on both sides, gray-green, becoming rigid, falcate and conduplicate, a peculiar habit not true of any other Iowa sunflower.

Heads: showy, numerous, terminal on stem and on short, densely

rough-pubescent peduncles from upper axils, disk 1.5-3 cm. broad, yellow.

Involucre: flat, bracts linear to lanceolate, 1.5-2.5 cm. long, attenuate into long slender tips, much longer than the disk, conspicuously gray strigose-canescent, loose and spreading.

Ray-flowers: 15-30, golden yellow, 2-4 cm. long, very concave.

Disk-flowers: 5.5 mm. long, dull yellow, slender, tube short, pubescent only along the veins of the corolla limb.

Chaff: 6-8 mm. long, linear, acute, very pubescent at apex and along keel.

Akene: brown, 4-5 mm. long, linear-oblong, striate, glabrous.

Pappus: 2 lanceolate short chaffy scales, frequently with 2 intermediate more rounded ones.

Underground parts: root, perennial with numerous thick woody branches; rhizomes short; crown buds at base of stem (Plate XXX, Fig. 4).

The variations in this species have to do mainly with the size of the plant. The dwarf few-flowered forms with simple low stem found in difficult surroundings are in striking contrast to the tall, more robust, many-flowered individuals of favorable environments. In cultivation it thrives, becoming an ornamental plant of distinctive character with larger and less conduplicate leaves. In the native haunts, when the falcate and conduplicate phase of the leaf is pronounced, the plants have a forlorn, wind-blown aspect, and give the impression of suffering from water loss.

It is distinguished from its near relatives *H. giganteus,* and *H. grosseserratus* by its gray appearance, the harsh conduplicate leaves, the rough-pubescent peduncles from the upper axils, the short internodes, and the more numerous, cupped ray-flowers.

H. Maximiliani was named after Maximilian Philip, Prince of Neuwied, who in the early nineteenth century travelled in Brazil and North America in the interest of natural science.

In North America, it ranges from Saskatchewan and Manitoba to Minnesota, Nebraska and Texas. It was first reported in Iowa in the northwestern part, though previously not known north of Lawrence, Kansas. In 1882, its known eastern limit was somewhat west of Des Moines. Its present distribution is more extended, having reached the southeastern part of the state (Pammel, 29). The writer secured plants of this species from railroad right-of-ways, roadsides in Dickinson County and from low places in Mus-

catine County. Herbarium specimens were from the counties of Madison, Lyon, Woodbury, Dickinson, Emmett, Scott, Fremont, Cherokee, Floyd, Carroll, Greene, Delaware and Cerro Gordo.

It is reported from the following counties: Buena Vista (12), Dickinson (12, 51), Dubuque (11, 12), Emmett (6, 12, 30, 49), Fayette (10, 15), Floyd (12, 42), Harrison (48), Johnson (56), Linn (60), Lyon (12, 45, 49, 51), Woodbury (12) and from the state of Iowa (17).

HELIANTHUS HIRSUTUS Raf.

Ann. Nat. 14. 1820.

Helianthus diversifolius Ell. Sketch 2:423. 1824.
Helianthus hispidulus Ell. l.c. 419. 1824.
Helianthus tracyphyllus T. & G. Fl. N. Am. 2:239. 1842.

Plate XXXI

Stem: 0.5-1.5 m. tall, simple or sometimes branching dichotomously above, rough-hirsute or hispid, somewhat glabrous below, rigid.

Leaves: opposite, ovate-lanceolate, acuminate, triple-nerved, nerves converging near base of blade, rounded, obtuse, or subcordate at base and subsessile or distinctly but short-petioled, margin sparsely serrate or slightly denticulate, usually firm, becoming rigid, scabrous, strumose and hispid above, hirsute-pubescent beneath.

Heads: solitary or many, cymosed, showy, disk yellow, 1.5-2 cm. broad, receptacle low-convex.

Involucre: hemispheric, bracts linear-lanceolate or oblong-lanceolate equalling the disk or not much exceeding it, loose, spreading, with acuminate recurved tips, puberulent over surface, hispidulous or short-ciliate on margins.

Ray-flowers: 1.5-2.5 cm. long, oval, yellow.

Disk-flowers: 5 mm. long, yellow, cylindrical, tube short, pubescent at base and on veins of limb and on the lobes.

Chaff: somewhat obtuse, lateral cusps short, pubescent at summit and along keel.

Akene: dark brown, 4 mm. long, thickish, obovate, entirely glabrous.

Pappus: 2 short-subulate awns, one-half as long as disk-flower, no other scales.

Underground parts: root perennial, woody; rhizomes clustered, stout.

This "Stiff-haired Sunflower" has been called polymorphous be-

cause of the extensive variation and lack of resemblance shown among the individuals of the species; the plants also change from youth to age, becoming more and more stiff and hirsute of stem and the leaf more harsh and firm. Two specimens, collector unnamed, which were examined in the herbarium of the Missouri Botanical Garden were of this stiff bristly-hairy nature with opposite, sessile, subsessile, or short-petioled leaves, 3-nerved, ovate, acuminate, slightly serrate, very rough above and rough-hairy beneath. The bracts of the involucre were ovate-lanceolate, equalling or shorter than the disk, erect and slightly spreading, densely villous-canescent. The rays numbered 10-12, the disk-flowers were yellow, pubescent, the akenes were oval, rounded at summit, glabrous.

It grows in dry soil, mostly on prairies and sunny banks, coming into bloom in August.

It is distributed from Ohio and Indiana to Wisconsin, south to Virginia, West Virginia, Tennessee, Louisiana, and Texas, and said to be adventive but not established eastward.

In Iowa it is a frequent prairie plant, rather common in dry thickets, on wooded bluffs, and along roadsides. The writer secured specimens from roadsides in Scott and Muscatine Counties.

Herbarium specimens were from Lee and Louisa Counties.

It is reported from the following counties: Appanoose (13), Decatur (13), Des Moines (12), Fayette (12, 15), Harrison (48), Johnson (12), Lee (12), Monona (48), Muscatine (4), Ringgold (12), Scott (4, 26), Van Buren (12, 13), and from the state of Iowa (17).

HELIANTHUS DIVARICATUS L.

Sp. pl. :906. 1753.

Helianthus truncatus Schwein. Ell. Sketch 2:416. 1824.

Plate XXXII

Stem: 0.5-2 m. or more tall, slender, simple or with dichotomous or trichotomous upper branches, mostly glabrous, often glaucous and purplish and sparsely hispid above and on flower branches.

Leaves: opposite throughout, spreading, ovate-lanceolate, occasionally narrower, acute or acuminate, rounded or truncate at base, 3-nerved at base of blade, sessile or subsessile or very short

petiolate, thickish, rough on both sides, or scabrous-pubescent below, hairs on veins ascending, deep green in sunny places, paler in the shade, not thin, crisp when dry.

Heads: few, often 3 in cymose form, or several somewhat panicled, disk 1-1.5 cm. broad.

Involucre: hemispheric, bracts 10-12 cm. long, lanceolate, or oblong-lanceolate from a broad base, acuminate, equalling the disk, at length squarrose and reflexed, 3-nerved, smooth or slightly pubescent, margin ciliate toward base.

Ray-flowers: 8-12, bright yellow, 2-2.5 cm. long, narrow.

Disk-flowers: 6-7 mm. long, yellow, tube short, lobes mostly glabrous, the very bulbous base pubescent.

Chaff: 7-8 mm. long, acute, or short acuminate, with 2 short, broad lateral cusps, keeled, pubescent at tip.

Akene: 4-5 mm. long, obovate, thickish, striate, glabrous.

Pappus: 2 short-subulate ciliate awns.

Underground parts: root perennial, of coarse fibers; rhizomes many.

This species is quite constant in its smooth stem, opposite, divaricate, sessile or nearly sessile leaves, with spreading pubescence below, the two or three heads on short peduncles in upper axils. Torrey and Gray[2] call it a polymorphous form, indicating its variability. Specimens in the herbarium of the Missouri Botanical Garden include a number designated as *H. divaricatus* L., which are short-petioled. Two plants collectd by George Engelmann have truly sessile leaves partly clasping, a specimen collected by E. Durand has leaves with truncate base and short petioles. The writer found no plants in the field with really sessile leaves, though in other respects they conformed to the type.

It is a plant of the dry soil of thickets and open woods. Coming into bloom in July and August it is the earliest of the sunflowers to reach maturity.

Its range is from Northwest Territory to New England, south to the Carolinas, Florida, and Louisiana. In Iowa it is common in dry thickets and edges of woods, where its showy heads look out during July, August and September. Herbarium specimens examined were from Madison, Union, Cerro Gordo, Des Moines, Allamakee, Fayette, and Winneshiek Counties.

It is reported from all parts of the state.

[2] Torrey, John and Asa Gray. A Flora of North America. 2:295. 1840.

HELIANTHUS STRUMOSUS L.

Sp. pl. 905. 1753.

Helianthus laevis Walt. Fl. Carol. 215. 1788.
Helianthus mollis Willd. Sp. pl. 3:2240. 1804.
Helianthus macrophyllus Willd. Hort. Berol. t. 70. 1806.
Helianthus decapetalus Darl. Fl. Cest. ed. 2:483. 1826.
Helianthus altissimus DC. Prodr. 5:590. 1834.
Helianthus strumosus var. *mollis* T. & G. Fl. N. Am. 2:327. 1842.
Helianthus neglectus Otto ex. A. Gray, Syn. Fl. N. Am. 2:279. 1849.

Plate XXXIII

Stem: 0.6-2 m. or more tall, round, slender, very smooth and glaucous below, purplish and sparsely hispid above.

Leaves: opposite, ovate-lanceolate, acuminate, 7-16 cm. long, 2-5 cm. broad, triple-nerved near the acute or rounded base, abruptly contracted at base and narrowed about half way to base of short petiole, petiole 0.5-1.5 cm. long, serrate, with small appressed teeth, rough strumose above, lower surface whitish, softly and evenly pubescent, hairs ascending.

Heads: solitary, or three to several, cymose on short peduncles from upper axils, disk 1-1.5 cm. broad, yellow, receptacle low convex.

Involucre: hemispheric, bracts broadly lanceolate, acuminate, equalling the disk, tips spreading, pubescent, ciliate on margins, strongly so toward base.

Ray-flowers: 12-15, bright yellow, 3-4 cm. long.

Disk-flowers: yellow, 5 mm. long, tube short, pubescent on bulbous base, veins and lobes.

Chaff: 8 mm. long, 3-cuspidate, middle cusp short acuminate, lateral cusps small, hairy-pubescent at summit.

Akenes: 3 mm. long, oblong or obovate, subcompressed, nearly glabrous or slightly pubescent at summit.

Pappus: 2 slender sub-chaffy awns nearly as long as the akenes.

Underground parts: root perennial, much branched; rhizomes.

Variations in this species are found in the size, texture of the leaves and the extent of the pubescence of the under surface. This under surface may be a lead-gray color, nearly white, or glabrous except for minute scattered hairs on the veins. Its constant characters are smooth stem, strictly opposite leaves and the one head, or a few heads in a cyme. It is distinguished from *H. decapetalus* L. and *H. tracheliifolius* Mill. by the bright leaves not membranous, the appressed-serrate margin, the strumose upper surface, the

whitish under surface, the broadly lanceolate bracts not exceeding the disk, and the akene pubescent at summit especially when young.

Helianthus strumosus is a dry woods species and is found also in thickets and copses. It blooms in August and September.

Its range extends from Maine to Ontario, northwest, southward to Missouri and Arkansas, and eastward to New Jersey and Virginia. In Iowa, it is widely distributed, common in woods and thickets. Plants were secured in these favored habitats in Dickinson, Muscatine, Johnson, and Scott Counties.

It is reported from the following counties: Dubuque (38), Emmett (7), Fayette (10, 15), Hardin (40), Harrison (48), Johnson (13), Madison (25), Mitchell (59), Monona (48), Muscatine (4), Scott (4), Story (20), Winneshiek (46) and from the state of Iowa (17).

Helianthus decapetalus L.

Sp. pl. 905. 1753.

Helianthus multiflorus L. Sp. pl. 905. 1753.
Helianthus frondosus L. Amoen. Acad. 4:290. 1759.
Helianthus strumosus Willd. Sp. pl. 3:2242. 1804.
Helianthus grandiflorus Juss. ex. Pers. Syn. 2:475. 1807.
Helianthus tenuifolius Ell. Sketch 2:420. 1824.
Helianthus scrophulariaefolius Britton Man. Fl. U. S. 1901.

Plate XXXIV

Stem: 1-2 m. tall, slender, simple but branching above, striate, green and smooth below, upper branches sometimes purplish and pubescent.

Leaves: opposite, upper sometimes alternate, oblong, ovate or sometimes cuneate at base, abruptly contracted into a somewhat winged or nearly naked petiole, triple-nerved above the base, long-acuminate, coarsely and sharply serrate, green both sides, scabrous above with very short stiff hairs often scattered, smooth or scabrous beneath, never pubescent, very thin and membranous, especially so in the pressed plant.

Heads: solitary or numerous on upper leafy branches; peduncles hispid, fastigiate, showy, disk rather small, yellow.

Involucre: somewhat companulate, bracts narrowly lanceolate-linear, loose, spreading but not reflexed, outer often longer than the disk, thin, often foliar, glabrous or slightly pubescent, very short ciliate on margins.

Ray-flowers: 8-12, light yellow, 2.6 cm. long, pubescent below on the orange colored veins.

Disk-flowers: yellow, tubular, slightly bulbous above the short tube, pubescent or puberulent throughout, especially on lobes and base.

Chaff: short, 3-cuspidate, the two lateral cusps small, acuminate, pubescent at apex and on keel.

Akene: brown, glabrous, somewhat appressed, ovate-oblong.

Pappus: 2 short slender subulate awns.

Underground parts: root perennial, of coarse fibers; rhizomes long, stout.

The variations in this species are found mostly in the size and texture of the leaf. When found growing in shady places the leaves become very large and broad with longer petioles, and very smooth lower surfaces. The outer involucral bracts are quite variable, sometimes becoming long and foliaceous; the rays are seldom ten in number, as *decapetalus* implies, more often there are twelve.

It is called the "Thin-leaved Sunflower" in contrast to *H. divaricatus* L. and *H. strumosus* L., whose leaves are thicker and more rough. Also, the large serratures, the more distinct petiole, the green under surface of the leaves, the longer, spreading bracts of the involucre and the entirely smooth akene separate it from these near relatives.

It is found in woods, copses and on shady banks along streams. It comes into bloom in August and September and is one of our most beautiful sunflowers. It has been long under cultivation as "Soleil d'Or".

Its distribution is from New England west to Michigan, Illinois, Kentucky, and Georgia. In Iowa, it is frequent, growing large and luxuriant in its favored haunts. The writer secured fine specimens with very large, thin, coarsely serrate leaves at the edge of a moist woods near the Little Sioux River in Dickinson County.

Herbarium specimens were from the counties of Lyon, Winneshiek, Lee, Emmett, Allamakee, Woodbury, Dubuque, Cerro Gordo, Iowa, Muscatine, and Louisa. It is reported from the following counties: Dickinson (51), Floyd (12), Johnson (56), Linn (60), Lyon (5), Madison (25), Muscatine (4), Scott (4), Webster (27), Winneshiek (46) and from the state of Iowa (17).

HELIANTHUS TRACHELIIFOLIUS Mill.

Gard. Dict. 8 ed, No. 7. 1768.

Helianthus prostratus Willd. Sp. pl., ed. 4, 3:2242. 1797.

Plate XXXV

Stem: 1-1.5 m. tall, erect, slender and simple, branched above, smooth toward base, pubescent above, in age rough with old hair bases.

Leaves: opposite, or alternate above, 8-15 cm. long, broadly lanceolate, never ovate, long acuminate, lower sharply and coarsely serrate or dentate, thin, nearly equally green on both sides, scabrous above, more or less pubescent or rough-haired below, triple-nerved, lateral nerves short, abruptly narrowed into distinct short petioles which are ciliate.

Heads: showy, 6.5-8 cm. broad, in loose racemose or cymose panicles, disk 1.5 cm. broad, yellow.

Involucre: campanulate, bracts lanceolate-linear, attenuate, longer than the disk, the exterior ones often extended into long subulate squarrose appendages, all loose and spreading, ciliate on margins, slightly so on surface, bases striate.

Ray-flowers: 10-15, light yellow, 3-4 cm. long, oval, pubescent along veins on under side.

Disk-flowers: about 5 mm. long, pubescent throughout or on base and lobes, slender and tapering.

Chaff: entire or barely 3-cuspidate, straw color below, grayish to blackish above, villous at apex and on keel.

Akene: dark, obovate, slightly truncate, glabrous.

Pappus: 2 broad, short, subulate awns.

Underground parts: root perennial, many fibers; rhizomes branched.

The specimen chosen for the foregoing description was loaned by the Field Museum Herbarium, and was collected by R. E. Means near Camp Douglas, Wis., Aug. 1890. Other plants designated as *H. tracheliifolius* were from the Missouri Botanical Garden and Iowa State College, Ames, Iowa.

The species closely resembles *H. strumosus* L. and also *H. decapetalus* L. and has been mentioned as a possible hybrid of these two strong species. It is a smaller form, distinguished by the thin leaves equally green on both sides, short though distinctly petioled and sharply serrate, and the bracts all loosely spreading, exceeding the disk and often elongated.

The habitat, like that of *H. strumosus*, is in dry thickets and edges of woods. It comes into bloom in August and continues through September.

It is distributed from Pennsylvania to Wisconsin, Missouri, and Arkansas. In Iowa it is said to be rare, infrequent or doubtful in low thickets and borders of woods.

Plants identified as this species were collected by the writer from open wooded hillsides, City Park, Cedar Rapids, Iowa. They possessed the almost strictly opposite leaves equally green on both sides, abruptly narrowed into short ciliate petioles, and the very striking long, loose and spreading outer involucral bracts. The underground parts, not present in any herbarium specimens seen, consisted of many fibers and several long branching rhizomes.

The species is reported from the following counties: Fayette (10, 12, 15), Henry (23), Johnson (12, 56), Muscatine (4), Story (12, 20) and from the state of Iowa (17).

HELIANTHUS TUBEROSUS L.

Sp. pl. 905. 1753.

Helianthus doronicoides T. & G. Fl. N. Amer. 2:327. 1841, in part not Lam.
Helianthus esculentus Warcz. Allg. Gartenz. 20:293. 1852.

Stem: 1.5-2.5 m. tall, stout, usually branched above, striate, scabrous and hirsute, less so near base.

Leaves: alternate, or frequently opposite below, 10-20 cm. long, commonly broad-ovate to ovate-lanceolate, lower often subcordate, acuminate, 3-nerved near base of blade, cuneate or narrowed abruptly into winged petioles 4-10 cm. long, with wings often obscure, shallowly serrate or somewhat dentate, thinnish, not coarse, nor yet membranous, green above, and firm scabrous-setose, lower surface somewhat densely spreading hispid-pubescent, not rough to the touch.

Heads: numerous and showy, panicled, disk 1.1-5 cm. broad, yellow, receptacle convex.

Involucre: hemispheric to campanulate, bracts linear to linear-lanceolate, variable, long-attenuate, loose and often squarrose, rather foliaceous, appressed-pubescent, long-ciliate or hirsute on margins toward base, a little (or much) longer than the disk, inner bracts dark purple toward base.

Ray-flowers: 12-20, bright yellow, 2.5-4 cm. long, tips obtuse, 1 cm. broad.

Disk-flowers: 5-7 mm. long, yellow, cylindrical, very pubescent at base, slightly so on lobes and main veins, barely bulged above the short tube.

Chaff: rather long, acute or slightly acuminate, often with 2 distant acute lateral cusps, long ciliate at tip and on keel.

Akene: 5-6 mm. long, dark brown, thick, angled, oblong, pubescent at summit and on angles.

Pappus: 2 subulate scales or chaffy awns about one-half the length of the disk corolla, rarely one or two intermediate fringy scales.

Underground parts: root perennial, of coarse fibers; rhizomes numerous, slender, bearing large edible tubers.

A number of specimens were used for the verification of this species in Iowa. One, loaned by the Field Museum Herbarium, was from the herbarium of J. T. Ruttnock, and found in moist ground, West Chester, Pennsylvania; others examined were from the herbarium of the Missouri Botanical Garden. Iowa specimens were loaned by Father Hauber of St. Ambrose College, Davenport, R. I. Cratty of the Iowa State College, Ames. Dr. Henry S. Conard of Grinnell College loaned specimens with tubers.

Variations are found chiefly in the leaves—their shapes, texture, serratures, and length of petiole. The pubescence of the under surface of leaves in some forms is so pronounced as to give rise to the variety *sub-canescens* Gray. This variety differs in many respects from the species and is readily recognized as something different. Plants found in Iowa herbaria and in the field are very constant in the following distinctions: usually smaller, very stiff and rigid, mostly simple, often bearing only one flower head, leaves more strictly opposite, thicker and coarser, lower ones large with coarse serratures, lower surface softly and densely canescent, involucral bracts very dark. A description typical of this varietal form will further aid in their recognition. (Page 367). Ternate forms are occasionally found. "A remarkable teratological form of this species with stem-leaves in whorls of three was collected in Wapello County, Sept. 3, 1929, by Dr. J. M. Aikman and the writer."[8] The plants do not always produce tubers, and only late in the fall do these form on the slender rhizomes. In cultivation, the entire plant is more luxuriant, producing many and much larger tubers.

Its native haunts are along fence rows, in old fields, along streams

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[8] Cratty, R. I. Iowa Plant Notes IV. Proc. Ia. Acad. Sci. 37:89. 1930.

in alluvial or almost any soil. It flowers from late August to middle October or until frost.

Probably introduced into North America from Brazil, it was long cultivated by the aborigines. Its cultivation and use as an article of food brought about its wide distribution over the whole of the United States and southern Canada, and it has had a long and interesting history connected with that of the early peoples and with the colonial development of our country. Gray and Trumbell[4] give an authentic account of its association with man from early times.

Many local names designate this species, such as Tuberous Helianthus, Earth Apple, Canada Potato, Girasole, Topinambour, and Jerusalem Artichoke. This last name probably is a corruption of the Italian *Girasoli articocco* (Sunflower Artichoke). From 1616 to 1753, it had fifteen botanical synonyms, when Linnaeus, in this latter year, called it *Helianthus tuberosus.*

Dr. A. Gray[5] believes that this edible sunflower originated in the Mississippi Valley from *H. doronicoides* Lam., a coarse species with showy heads which is said to grow in river bottoms from Ohio to Illinois and southward.

H. tuberosus is distributed from Nova Scotia, New Brunswick, Quebec and Ontario southward to New York, New Jersey, Pennsylvania, Georgia, Minnesota, Missouri, Nebraska, Arkansas and westward. In Iowa, it has a wide distribution and also has become naturalized from gardens. It is frequent in low moist ground, low woods, abundant in open places, borders of woods and fields, and is reported as found on new levees and in sand and gravel areas. Abundant material was taken from fence rows in Dickinson County, along Duck Creek near Davenport, roadsides and open places in Scott County. In late September, 1933, the writer secured from the garden of Mr. J. M. Hitchings, Davenport, very large, splendid specimens of *H. tuberosus.* They ranged from 2-5 m. in height, were mostly simple, but ramosely branched above, and bore several to many medium sized heads on slender branches from the upper axils. The leaves were quite typical of the species, being mostly alternate except below. Each plant produced many tubers of various sizes

[4] Gray, A. and J. H. Trumbell. Review of De Candolle's Origin of Cultivated Plants, with annotations on certain American species. Amer. Jour. Sci. 26:128-138. 1883.

[5] Gray, A. The Jerusalem artichoke once more. Amer. Agri. 36:142. 1877.

and shapes and these were quite edible. Herbarium specimens were from many localities in all parts of the state.

It is reported in all county and state lists.

HELIANTHUS TUBEROSUS VAR. SUBCANESCENS Gray
Syn. Fl. N.A. 1(2):280. 1884.

Helianthus subcanescens (Gray) Watson. Rep. Mich. Acad. Sci., Arts and Letters. 9:430. 1928.

Helianthus mollissimus Watson. Rep. Mich. Acad. Sci., Arts and Letters. 9:432. 1928.

Stem: 1.1 m. tall, stout, stiff and rigid, stramineous, densely scabrous-hispid, simple, leafy to the top.

Leaves: strictly opposite, ovate below to linear-lanceolate above, acute or some acuminate, narrowed to base of petiole or petiole almost distinct, margin coarsely, evenly serrate on lower leaves, serrulate to nearly entire above, 3-nerved above the base, upper surface antrorse strumose-hispid, lower surface densely soft strigose-canescent giving whitish appearance.

Heads: solitary to few, cymose, peduncles short.

Involucre: campanulate, bracts narrow linear-lanceolate, attenuate, some longer than disk, erect, loose, later reflexed, dark green, hispidulous only toward apex, ciliate on margins.

Ray-flowers: 15, with orange veins, pubescent on back, 2 cm. long.

Disk-flowers: yellow, cylindrical, slightly pubescent on lobes and veins, densely so on base.

Chaff: tricuspid, lateral cusps small, apex acute, canescent on tips and keel.

Akene: linear, brown, flattened though slightly angled, canescent at summit and somewhat down the angles.

Pappus: 2 slender chaffy awns with enlarged bases, 1/2 as long as disk-flower.

Underground parts: root perennial, fibrous; rhizomes bearing tubers.

Watson raises this more canescent form of *Helianthus tuberosus* to the species rank because of "the invariably opposite leaves of thick coarse texture with densely pubescent under surface." His *H. mollissimus*, synonymous with var. *subcanescens* Gray, has narrower, more attenuate bracts, not dark green, but almost hoary with dense hispidity, the inflorescence more ample, rays longer, disk-flowers glabrous except the very pubescent base, the leaves

oblong, more scabrose-setose above and more densely tomentose below. Plants with these distinctions are here included under var. *subcanescens.*

Both forms are said to be distributed in the middle west, Illinois, Wisconsin, Minnesota to Missouri westward, *mollissimus* being also listed for Ohio. Specimens believed to be var. *subcanescens* were collected by the writer in Scott County along Orphans' Home road and Smith's road near Davenport, and in Muscatine County near Wyoming Hill. Others were from the roadside southwest of Kendalville, Winneshiek County, collected by B. Shimek, Sept. 1st, 1926.

HELIANTHUS TOMENTOSUS Michx.
Fl. Am. Bor. 2:141. 1803.

Helianthus spathulatus Ell. Sketch, 2:421. 1824.
Helianthus squarrosus Nutt. Trans. Amer. Phil. Soc. 7:367. 1841.

Stem: 1-2.5 m. tall, simple to the inflorescence, scabrous, hairy-pubescent or hispid above, somewhat glabrous below, variable, the hairs spreading or retrorse, reddish.

Leaves: opposite below, alternate above, variable, oblong-lanceolate, or lowest ovate tapering at both ends, 3-nerved near base of blade, narrowed to base of petiole, rarely with lower portion of petiole distinct, obscurely serrate, 1.5-3 dm. long, 2-8 cm. broad, deep green, scabrous above, densely or thinly soft-pubescent below, hairs spreading to retrorse, resin-dotted.

Heads: several, racemose or panicled on short scabrous peduncles, disks about 2 cm. broad, yellowish.

Involucre: bracts linear-lanceolate, long acuminate, densely hirsute and ciliate, often much longer than the disk, spreading and squarrose, resin dotted, in mature heads very abruptly reflexed.

Ray-flowers: 12-16, about 2.5-3 cm. long, bright yellow, pubescent beneath along the veins, resin-dotted.

Disk-flowers: yellowish, tube short, lobes and base very pubescent.

Chaff: large, 3-cuspidate, middle cusp large, acute, tip and keel very pubescent.

Akene: 5-6 mm. long, brown, thick, somewhat angled, smooth.

Pappus: 2 slender awns, about 3 mm. long.

Underground parts: root perennial, woody, thick; rhizomes few.

This species is extremely variable as to the hirsute nature of

stem and leaves, and the size of the leaves and the extent of the decurrence upon the petiole.

It thrives in rich woods, on hillsides and in dry soil. Its range is throughout the southern states and it is not included in Iowa flora by Gray's Manual, 7th Edition. It is reported from Illinois and Iowa, no doubt, erroneously. (Pammel, 39).

Specimens examined in the herbarium of the Missouri Botanical Garden were collected by John K. Small, in Nacoochee Valley, White County, Georgia, in September, 1894, and by Geo. Engelmann, Cambridge Botanical Gardens, September, 1856. One was a teratological form. A specimen in the Field Museum herbarium was collected by John K. Small, near Chimney Rock, North Carolina, October, 1901.

HELIANTHUS DORONICOIDES Lam.

Encyc. 3:84. 1789.

Helianthus Hookeri G. Don. Lond. Hort. Brit. 358. 1827.
Helianthus pilosus Tausch. Fl. 11:502. 1828.
Helianthus cinereus var. *Sullivanti* T. & G. Fl. N. Am. 3:324. 1842.

Plate XXXVI

Stem: 1-3 m. tall, simple but branched above, smooth below, scabrous-pubescent to hirsute above, hairs spreading, flowering branches ascending.

Leaves: opposite below, alternate above, occasionally all opposite, ovate to ovate-lanceolate, acute or acuminate, 1-3 dm. long, shallowly serrate or upper entire, 3-nerved somewhat below the middle, abruptly narrowed but broadly decurrent to base of petiole, therefore sessile; scabrous-hispid above, softly tomentose below, hairs on midrib and veins long and somewhat spreading-antrorse.

Heads: several, showy, loosely panicled on short leafy hirsute ascending peduncles, disk yellow, 1.5-2 cm. broad.

Involucre: hemispheric, bracts 1.5-1.8 cm. long, attenuate, spreading and reflexed, surface densely hirsute, long spreading-ciliate on margin, base striate.

Ray-flowers: 12-20, bright yellow, 2.5-4 cm. long, 1-1.2 cm. broad, oval.

Disk-flowers: 5 mm. long, yellow, only slightly bulged at base of limb, which is rather densely villous.

Chaff: large, 8 mm. long, 3-cuspidate, apex acuminate, dark in color, hairy at summit and on upper part of keel.

Akene: 5 mm. long, oblong-oval, flattened, not much keeled, glabrous.

Pappus: 2 lanceolate awns with broad chaffy bases.

Underground parts: root perennial; rhizomes short, thick.

This species may be recognized by its general pubescence and spreading antrorse hispidity, the soft tomentose lower leaf-surface, the showy heads on short ascending branches and the spreading to reflexed involucral bracts very hirsute and ciliate. The most notable feature is the large sessile leaf triple-nerved only a little below the middle of the blade, and gradually narrowed to the base of the petiole. No species of sunflower of this region possesses this characteristic. Usually, leaves of Helianthus are 3-nerved, and more or less abruptly narrowed at the base of the blade, and are sessile, distinctly petioled, or narrowed to the base of the petiole.

It resembles *H. tomentosus* Michx, but the pecular leaves, more hairy involucral bracts, and the absence of resin distinguish it from this near relative. From *H. mollis* Lam., also a close relative, it differs in its peculiar leaf, in being taller with shorter peduncles and in the longer, looser, more hairy involucral bracts.

It is an inhabitant of fields, river bottoms, and dry soil, blooming from August to October. Often grown in cultivation, it is said to be the ancestral form of *H. tuberosus* L.

Its range is from Michigan, Illinois, Ohio, Missouri, Arkansas, throughout the western and inland portions of the southern states.

The specimen examined and here described was loaned by the herbarium of the Field Museum, and was collected by E. Hall near Spring Creek, Sangamon County, Illinois, September, 1860. Other specimens designated as *H. doronicoides* Lam. were from the Missouri Botanical Garden.

The writer has found no plants in the field nor in Iowa herbaria which conformed to the verified specimen examined.

It is reported by J. C. Arthur (2).

HELIANTHUS ATRORUBENS L.
Sp. pl. 906. 1753.

Helianthus sparsifolius Ell. Sketch 2:415. 1848.
Helianthus atrorubens normalis Kuntze Rev. Gen. 1:343. 1891.

Stem: 0.5-1.5 m. tall, slender, branched above, very rough and hairy with long white hairs, smooth to glabrate and naked above.

Leaves: 8-20 cm. or more long, 5-12 cm. broad, mainly on lower part of stem, mostly opposite, upper in small distant pairs, uppermost bract-like, sometimes alternate, ovate, oval, or spatulate-oblong, apex obtuse, 3-nerved, cuneate, truncate, or slightly cordate at base, abruptly contracted and narrowed to the base of the long petiole, often as long as the blade, margin crenate-serrate to nearly entire in upper leaves, veiny, thinnish, but of coarse texture, both sides hirsute or strigose-hispid, hairs on midrib spreading to retrorse.

Heads: 3-7 in open corymbose-panicle, on long slender peduncles bearing a few small bract-like leaves, small but showy, disk dark, about 1.5 cm. broad, receptacle convex.

Involucre: broad campanulate, bracts 9 mm. long, ovate to oblong, shorter than disk, obtuse or mucronate-tipped, unequal, leathery, glabrous or minutely ciliate when immature, appressed, deep green.

Ray-flowers: 10-16, bright yellow, 1.5-2 cm. long.

Disk-flowers: 5 mm. long, lobes dark purple, throat and base yellow, slightly pubescent at base and on veins and lobes.

Chaff: 9 mm. long, entire or barely tricuspid, apex purplish, pubescent, acuminate, exceeding the disk-flowers.

Akene: 3 mm. long, 4-angled, thickish, dark brown, oblong to obovate, entirely pubescent when young, pubescent at summit when mature.

Pappus: 2 thin minutely fringed lanceolate squamellate awns, about 2.5 mm. long.

Underground parts: root perennial, fibrous.

The specimen examined was from a wooded mountain side near Asheville, North Carolina, and was loaned by the Field Museum Herbarium. It was a typical plant of this distinctly marked species, which should never be confused with any other sunflower. Its most striking features are the harsh leaves with their blades narrowed from the abruptly contracted base to the base of the long petiole and the unequal but strictly oblong bracts. Its generally coarse and hairy aspects, the small purple disks, the short bright yellow rays, and the pubescent akenes, combine to make it a very striking and interesting sunflower. As its name implies, "Hairy Wood-Sunflower", its habitat is in and about the open woods. It blooms from August to October.

It is reported in the manuals as ranging south from Virginia to

Florida, Louisiana, Arkansas, west to Missouri, and "said to extend northward to Minnesota" (Gray's Manual, 7 ed.). This distribution, of course, would cover Iowa, but no specimen was found in the field nor in Iowa herbaria. It is not reported by any Iowa author.

GENUS COREOPSIS L.

Sp. Pl. 907. 1753.

Ascespermum Neck. Elem. 1:34. 1790.
Coreopsides Moench. Meth. 594. 1794.
Anacis Schrank, in Denkschr. Acad. Muench. 5:5. 1817.
Leachia Cass. in Dict. Sc. Nat. 25:388. 1822.
Diodonta Tausch. Hort. Canal. Soc. ser. 2, 7:360. 1823.
Calliopsis Reichb. Ic. et Descr. pl.l.t. 10. 1824.
Campylotheca Cass. Dict. Sc. Nat. 51:476. 1826.
Dolicotheca Cass. Dict. Sc. Nat. 51:476. 1826.
Chrysomelea Tausch. Hort. Canal. 227. 1832.
Electra DC. Prodr. 5:568. 1836.
Agarista DC. Prodr. 5:569. 1836.
Leptosyne DC. Prodr. 5:531. 1836.
Peramibus Rafin. ex. DC. Prodr. 5:568. 1836.
Epilepsis Benth. Pl. Hartw. 17. 1839.
Prestinaria Sch. Bip. ex. Steud. Nom. Ed. 2:393. 1841.
Diadonta Walp. Rep. 2:614. 1843.
Pugiopappus Gray, In Torrey, Botany U. S. War Dept. Expl. R.R. to the Pacific 4:104. 1856.

Coreopsis, from the Greek κόρις meaning "a bug," and ὄψις "appearance", alludes to the insect-like form of the fruit.

The genus is a primitive member of the tribe Heliantheae, and, like *Bidens,* is thought to have been derived, through the genus *Spilanthe,* from the earliest composite form, *Senecio.*[6] Contemporaneously with *Bidens, Coreopsis* appeared as early as the upper Pliocene Period of the Tertiary Age in northern South America (regions of Peru, Chile, and Bolivia). Both genera reached their greatest development in Mexico, whence they spread chiefly along mountain ranges to all parts of the temperate and tropical western hemisphere, to Alaska, and to the eastern hemisphere. This wide distribution, and the great number of species developed, together

[6] Small, J. The origin and development of the Compositae. New Phytologist. Repr. 11:309. 1919.

with abundant fossil remains, confirm the accepted view of the early origin of these two closely related genera.

The given number of species in the genus *Coreopsis* varies greatly because of the various interpretations by authors of the awn characters of the akenes. Nuttall (1859) records thirty species extending into the southern hemisphere as far as Peru; Bentham (1873) lists a total of forty species for America with twenty-seven in the United States, ten in Mexico and six in the Andean region; MacMillan (1892) gives seventy to seventy-five species with thirty in North America, seven in Canada, eighteen in the eastern states and twenty in the southern states; Britton and Brown (1913) name fifty species native to the Americas and Australasia. For the territory covered by Gray's Manual, 7th edition, eleven species are included. In Iowa, the two well known species are *C.tripteris* L. and *C.palmata* Nutt. Two others, *C.lanceolata* L. and *C.tinctoria* Nutt. are reported for Iowa, but they are here considered as escapes from gardens.

They are annual or perennial herbs of the drier areas and show interesting adaptations to this environment. Their rigid habit of growth, scabrous surface of stem, and the thick smooth coriaceous leaves are in strong contrast with the generally softer, weaker, more mesophytic or helophytic species of the genus *Bidens*.

Additional features which distinguish the genus are as follows:

Leaves: opposite, of various pinnate forms, or simple with scarious margins.

Heads: small, few to numerous, radiate, the rays neutral, yellow or partly purple-colored, the disk-flowers tubular, 5-lobed, perfect and fertile, anthers entire at base, style-arms truncate, or abruptly cuspidate.

Involucre: a double series of bracts, the outer 8 small, narrow, foliaceous, somewhat spreading, united at base; the inner broad, colored, appressed, almost membranaceous with thin scarious margins, united to about the middle.

Chaff: thin, concave, deciduous with akenes.

Akenes: flat, obcompressed, usually winged, naked at summit, two-toothed, awned, or with a coroniform border.

The important generic distinctions between *Coreopsis* and *Bidens* are found in the involucre and in the margin and awn development of the akene. In Coreopsis the floral distinctions are the smaller, more scarious, somewhat colored inner bracts united toward the

base, the usually winged akene not much narrowed at the summit and practically devoid of any real awn outgrowth. The direction of awn and achenal barbs and hairs is now regarded as too variable and trivial to have generic value. The antrorse feature is no longer held to delimit *Coreopsis* nor the retrorse to delimit *Bidens*.

Key to Species of Genus Coreopsis

a. Stem 1-2.5 m. tall, simple but corymbed at top; leaves petiolate, pinnately 3-5-divided to base, upper undivided..*C. tripteris*

a. Stem 3-9 dm. tall, simple; leaves sessile, mostly 3-divided only half way, upper undivided ....*C. palmata*

Coreopsis tripteris L.

Sp. pl. 908. 1753.

Chrysostemma tripteris (L.) Less. Syn. 227. 1832.

Stem: 1-2.5 m. tall, glabrous, strict, rather slender, ternate, simple below, with corymbose flowering branches above, leafy throughout.

Leaves: opposite, petioled, firm, either glabrous or minutely scabrous-puberulent; the radical leaves 5-pinnate, the cauline leaves trifoliate, frequently the middle leaflet again divided; margin very scabrous and with a marginal nerve with which the veins are joined; uppermost leaves simple and entire.

Heads: small, 4-5 cm. broad, numerous on short slender corymbose or fastigiate peduncles, anise-scented when bruised.

Involucre: outer bracts 8, united at base, linear, 2-3 mm. long, narrow, obtuse, short-pubescent; inner bracts 8, ovate, somewhat acute, with yellowish margins, pubescent.

Ray-flowers: 6-10, usually 8, yellow, elliptic-oblong, entire and obtuse, or notched.

Disk-flowers: dull yellow, later brownish, a purple line between the lobes, the 5 lobes erect.

Chaff: linear-spatulate, longer than disk-flowers, obtuse, membranaceous, purple lined, deciduous with akenes.

Akenes: flat, elliptic-oblong to obovate, 5-6 mm. long, brown, narrowly winged, emarginate at summit.

Pappus: a denticulate fringe, fimbriate, nearly confined to the wing, hardly a pappus.

Root: Perennial.

The characters of this species are very pronounced and quite con-

stant. Variations have to do with the extent of branching toward the upper part, the number of heads, and slight modifications of the pinnate leaf-forms. It is rightly called the "Tall Coreopsis" or "Tall Tickseed". Groups of the tall, slender, leafy plants much branched at the top, and bearing numerous small orange-yellow heads make many a bright spot in moist thickets, and along dry borders of streams. It is common on prairies, perferring the lower moist places where it becomes very luxuriant. It blooms through July and August.

In America, this species is widely distributed from Canada to Pennsylvania, Virginia, Carolina and Florida, westward to Missouri, Nebraska, Louisiana and western Texas. In Iowa, it is frequent in low places along roadsides and railroads, on prairies and open woods. Abundant material was found in such places and in the herbaria.

It is reported as common from all parts of the state.

COREOPSIS PALMATA Nutt.

Gen. 2:180. 1818.

Coreopsis pauciflora Lehm. Ind. Sem. Hamb. 1833.
Coreopsis praecox Fresn. Ind. Sem. Hort. France. 1838.

Plate XXXVII

Stem: 5-9 dm. tall, erect, nearly smooth, rigid, simple or some branched, angled, striate, leafy to the top.

Leaves: opposite, sessile, more or less divaricate; pale green, thick and rigid, glabrous or subcoriaceous; 3-cleft to about the middle; the uppermost simple; obtuse with scabrous margins.

Heads: small, 2.5-5 cm. broad, solitary or sometimes several (3-7) on short peduncles.

Involucre: outer 8 bracts 7-9 mm. long, linear, rigid, obtuse, glabrous; inner bracts oblong-ovate, longer than outer bracts, yellowish, nearly membranaceous.

Ray-flowers: 8, oblong-ovate, entire or 3-notched, bright yellow.

Disk-flowers: yellow, the five lobes erect or incurved.

Chaff: linear, acute, slightly dilated at summit, shorter than disk-flowers, deciduous with akenes.

Akenes: obovate or elliptic-oblong, truncate, smooth, narrowly winged, emarginate at summit.

Pappus: really none, or slight extentions of the wings into 2 short obscure teeth, often deciduous.

Root: perennial.

The few and slight variations in this species are confined to the extent of branching and to the number of heads at the top of the plant. The leaves are quite uniformly 3-cleft below, and simple above. Ternate-leaved variants occasionally are found.

Coreopsis palmata Nutt., known as the "Stiff Tickseed", is readily recognized as it stiffly sways among the grasses of the dry prairies and sunny hillsides. It occurs also in open woods and on sand and gravel areas. (Shimek, 52). One of the early composites to come into bloom, it lasts only through June and July, few blossoms appearing in August.

In North America it ranges from Manitoba, Michigan, Minnesota throughout the Minnesota valley, to Nebraska, Arkansas and western Texas. In Iowa, it is common on the prairie throughout the state, growing in small isolated groups or as scattered individuals. Abundant material was secured in field and herbaria.

It is included in all county and state prairie lists.

GENUS BIDENS L.

Sp. Pl. 831. 1753.

Pluridens Neck. Elem. 1:86. 1790.
Edwarsia Neck. Elem. 1:87. 1790.
Kerneria Moench. Meth. 595. 1794.
Ceratocephalus Vaill. ex. Cass. Dict. Sc. Nat. 7:432. 1817.
Delucia DC. Prodr. 5:633. 1836.

Bidens, from the Latin meaning "having two teeth", refers to the pappus of persistent rigid awns. By the lateral fusing of many setae a few aristae are formed, usually two to four. The barbs of the aristae are merely the slightly projecting free ends of the setae, sharp thornlike structures, which may be erect (antrorse) or reflexed (retrorse).

This awn type of fruit-distributing organ, dominant in the Tribe Heliantheae, appeared later geologically than the capillary type found in *Senecio*, and probably developed from the latter wind-carrier. When the slowly rising Rockies and Andes restricted the wind-swept areas where the capillary type of pappus had long been the successful organ of dispersal, animals of forest and plain became

the efficient dispersers of seeds. The fusion of setae, with free ends extended into barbs, thus resulted in a world-wide distribution of this genus. The great number of species universally distributed, and the abundant fossil remains found in the Upper Pliocene Period of the Tertiary Age further indicate the early origin of *Bidens* (Small 1919).

It is certain that South America (Brazil and Chile) was the original home of *Bidens* and related genera, the regions of greatest development being Mexico and the United States. Their spread throughout temperate and tropical regions of both hemispheres developed new species nonexistent in their first home.

The early distinction made between the two closely related genera, *Coreopsis* and *Bidens,* was based chiefly upon the direction of the akenal hairs and of the barbs of the awns. Species with antrorse awn-character were included in *Coreopsis,* and others with retrorse awn-character were included in *Bidens.* Britton[7] in 1893, noted the variability and the unreliability of this distinction as a generic feature. He says: "This character has been found completely to fail in the case of *Bidens frondosa* L. which has both or neither, and *B. discoidea* T. & G., I have observed with downward barbs."

Abandoning this awn trait, he was able, then, to transfer to *Bidens* the six forms included in *Coreopsis* having antrorse awns but otherwise with strong Bidens characters. These species as they now stand are: *B. bidentoides* (Nutt.) Britton, *B. aristosa* (Michx.) Britton, *B. coronata* (L.) Fischer, *B. trichosperma* (Michx.) Britton, and var. *tenuiloba* (Gray) Britton. *B. involucrata* (Nutt.) Britton, and *B. discoidea* (T. & G.) Britton.

Dr. E. E. Sherff,[8] after world-wide study of *Coreopsis* and *Bidens,* observes that there remains no absolute uniformity in even one distinctive character. He adds that the presence in *Coreopsis* and the absence in *Bidens* of the two lateral wings on mature akenes is the most strikingly constant character and often is the only basis of distinction. He thus clearly summarizes the limits of these two genera: "*Coreopsis* is maintained because of its peculiar habit and the winged akenes of the Linnaean type species. *Bidens* is maintained primarily because of the peculiar habit, the strongly barbed awns, and wingless akenes of several of the Linnaean type species."

This genus is now made up of some ninety recorded species, large-

7 Britton, N. L. New or noteworthy Phanerogams. VII. Bull. Torr. Bot. Club 20:281. 1893.

8 Sherff, E. E. Studies in Bidens II. Bot. Gaz. 59:301. 1915.

ly of the American tropical and temperate regions but also naturalized in Europe, Asia, and Africa. Of the twenty-two or more species known in the United States, fifteen are included in the area covered by Gray's Manual, 7th edition. In Iowa, ten species are known: *B. cernua* L., *B. connata* Muhl., *B. comosa* (Gray) Wieg., *B. frondosa* L., *B. vulgata* Greene, *B. Beckii* Torr., *B. aristosa* (Michx.) Britton, *B. involucrata* (Nutt.) Britton, *B. trichosperma* (Michx.) Britton, and *B. bipinnata* L. The following three species are also reported for Iowa: *B. discoidea* (T. & G.) Britton, *B. laevis* (L.) BSP. and *B. coronata* (L.) Fisch. It is believed, however, that these reported species do not exist in the state, and that the names have been applied erroneously to plant forms in Iowa somewhat resembling these species.

The species of Bidens are mostly annuals of the weedy type common to moist areas and waste places, and are listed among the obnoxious weed flora. The characters which distinguish the genus from the other genera of the tribe are as follows:

Leaves: opposite and various, simple or 3-5 segmented, petioled or connate.

Heads: small, radiate or discoid.

Receptacle: mostly flat or slightly convex, chaffy.

Involucre: double, outer commonly large, foliaceous, inner small, membranaceous, striate, somewhat colored.

Ray-flowers: 8, yellow, neutral, absent in some.

Disk-flowers: numerous, tubular, mostly 5-lobed, yellowish or bright yellow, stamens and pistil exserted in some, entire or barely sagittate at base, style-arms subulate-tipped.

Chaff: slender, 3-5 striate, membranaceous, subtending the disk-flowers, deciduous with flowers or fruit.

Akenes: flattened parallel to the bracts, or slender, 3-4-sided, margins antrorsely or retrorsely hispid, rarely corky, entire or crenulate.

Pappus: 2-4 awns, or short teeth antrorsely or retrorsely barbed, sometimes absent.

The striking features distinguishing the species within the genus are the leaf-forms, the presence or absence of ray-flowers, the number of corolla-lobes in the disk-flowers, the number and length of the outer involucral bracts, and, chiefly perhaps, the number, length, and barbed condition of the awns of the akenes.

Key to Species of Genus Bidens

a. Leaves simple, mostly undivided; awns retrorsely barbed . . . . b.

b. Heads radiate, mostly nodding in fruit; leaves sessile or connate . . . . c.

c. Rays $1\frac{1}{2}$ times as long as disk; akenes wedge-obovate, strongly keeled, with light corky margins. *B. cernua*

c. Rays larger; akenes cuneate, not strongly keeled, without corky margins. *B. laevis*

b. Heads discoid, erect; leaves petiolate or connate . . . . d.

d. Leaves slender petioled, lower often deeply parted; akene narrowly cuneate, 4-angled, 4-awned; disk-flower 5-toothed, orange-yellow. *B. connata*

d. Leaves connate, all entire; akene flattened, scarcely angled, mostly 3-awned; disk-flower 4-toothed, pale yellow. *B. comosa*

a. Leaves mostly pinnate or finely dissected; awns antrorsely or retrorsely barbed . . . . e.

e. Leaves mostly immersed, finely dissected; heads conspicuously radiate. *B. Beckii*

e. Leaves aerial, pinnate; heads discoid, or radiate . . . . f.

f. Leaves ternately compound; outer bracts 4, much exceeding disk; akenes and awns antrorsely barbed. *B. discoidea*

f. Leaves pinnate with 3-7 leaflets; outer bracts several, equalling or exceeding disks; awns retrorsely barbed . . . . g.

g. Akenes oblong spindle-shape, antrorsely barbed, 3-4 awned; leaves often 2-3 pinnatifid. *B. bipinnata*

g. Akenes flattened, antrorsely or retrorsely barbed, 2-awned; leaves 1-pinnate. . . . h.

h. Heads discoid, or rays few and small, outer bracts exceeding disk; awns mostly retrorsely barbed, rarely antrorse . . . .i.

i. Outer bracts ciliate; akenes cuneate, black, slightly hairy. *B. frondosa*

i. Outer bracts hispid-ciliate, akenes oblong-cuneate to obovate; brown, smooth or tuberculate. *B. vulgata*

h. Heads radiate, rays conspicuous; outer bracts not exceeding disk; awns, if present, antrorsely barbed or hispid . . . . j.

j. Akenes narrowly wedge-oblong, not margined; awns awl-shaped. *B. trichosperma*

j. Akenes elliptic-obovate with thin scarious margins; awns long or reduced to short teeth, or absent . . . . k.

k. Outer bracts longer than inner, coarsely hispid, akenes strigose-hispid, especially on margins. *B. involucrata*

k. Outer bracts shorter than inner, smooth or ciliate; akenes slightly hispid or pubescent . . . . l.

l. Margins of akenes crenate, awns long and slender, or reduced to short teeth or wanting; leaves all pinnate. *B. aristosa*

l. **Margins of akenes not crenate, but very narrowly winged; awns 2 short blunt teeth; leaves sometimes simple or only slightly divided. *B. coronata***

BIDENS CERNUA L.

Sp. pl. 832. 1753.

Coreopsis bidens L. l. c. 908. 1753.
Bidens minima L. l. c. 908. 1753.
Bidens cernua var. *elata* T. & G. Fl. 2:352. 1841.
Bidens quadriaristata var. *dentata* Nutt. Trans. Amer. Phil. Soc. 7:368. 1841.
Bidens gracilis Greene, Pittonia 4:255. 1901.

Stem: 3-6 dm. tall, erect to somewhat procumbent, branches short, decreasing in length toward the base, pale green, smooth, or setulose-hispid toward the top.

Leaves: opposite, simple, smooth and glabrous, linear-lanceolate, acuminate, the upper narrowed into a connate or subconnate base, the lower merely opposite and sessile, margin with coarse unequal distant teeth.

Heads: wider than high, mostly solitary, nodding in maturity or small and young heads erect, discoid or radiate.

Involucre: bracts 6-7, unequal, longer than the head, usually foliaceous, often three or four times as long as the disk, erect and very conspicuous, inner bracts with membranous margins, not purple-tipped.

Ray-flowers: 8 yellow, sometimes absent.

Disk-flowers: narrowed about the middle, 5-lobed, orange-yellow, smooth.

Chaff: slender, orange-yellow tipped, deciduous with akenes.

Akenes: dark brown or greenish, often curved, obovate to cuneate or wedge-shaped rhomboidal, somewhat dilated at the summit, strongly 4-angled, tuberculate on angles, the light corky margins retrorsely ciliate-hispid.

Pappus: 4 (sometimes 2 or 3) slender erect awns retrorsely barbed.

It seems that no plant could be more variable in all its parts. In a single patch will be found small procumbent forms bearing one or two large radiate or discoid nodding heads, or small erect heads with involucral bracts not much exceeding the disk; there will be found large erect forms with long foliaceous involucral bracts and many other intermediate forms not much resembling these two ex-

treme vegetative phases of the species. For this reason, much confusion has existed and many new species names have been proposed, later to be reduced to synonomy or applied to varieties. The large forms with erect radiate heads resemble *B. laevis* (L.) BSP. and often are reported as such, but this latter species is not included in the region covered by Gray's Manual, 7th edition, nor in Iowa.

This "Nodding Bur Marigold" is said to have been introduced from Europe. Its range in North America is from Nova Scotia and New Brunswick to Hudson Bay, and from Saskatchewan to Montana and Oregon, south to Virginia, Missouri, and Colorado. In Iowa, it is one of the most common and abundant species of the marshes, swamps, and other wet places, as shores of rivers and ponds. It is rather common in peat and sedge bogs though more abundant where these areas have been drained. (Pammel, 34).

Abundant material was secured from all swamp areas visited by the writer and the state herbaria abound in specimens in all vegetative and floral phases.

It is reported as an abundant and wide-spread swamp species in all parts of the state.

BIDENS CONNATA Muhl.

Willd. Sp. pl. 3:1718. 1804.

Bidens tripartita Bigl. Fl. Bost. 2nd ed. 2:294. 1824.
Bidens petiolata Nutt. Journ. Acad. Phil. 7:99. 1834.

Plate XXXVIII

Stem: 0.5-1.5 m. tall, moderately and loosely branching, with rather long internodes, glabrous, striate, bright green, or upper stem and branches purplish.

Leaves: opposite, bright green, mostly simple, lanceolate to elliptical, acuminate, tapering to the slender and slightly connate petioles, the lower leaves sometimes deeply 3-parted with the lateral segments connate at base and narrowed on the petiole.

Heads: medium, usually discoid, 1.5 cm. broad, several to numerous on short peduncles.

Involucre: outer bracts 4 or 5, linear-spatulate to lanceolate, mostly obtuse, much exceeding the disk, glabrous or scarcely at all ciliate, inner bracts about 8, ovate and obtuse, often keeled, 7-8 mm. long, brownish.

Ray-flowers: wanting or rarely present, inconspicuous, golden yellow.

Disk-flowers: 5-lobed, deep orange-color, narrowed below the middle, stamens and pistil often exserted.

Chaff: slender, slightly longer than the disk-flower, or a little shorter.

Akenes: 4-5 mm. long, dark green or nearly black, cuneate, outer akenes obovate and thick, 4-angled, often keeled, glabrous or slightly hairy and with brownish or light colored warts, margins retrorsely hispid or some marginal barbs antrorse toward base, young akenes hairy, often awnless.

Pappus: of 2, 3, or 4 slender awns ¼-½ the length of the akene, retrorsely or occasionally antrorsely barbed, inner akenes with hispid-ciliate awns, or none.

Root: annual, fibrous.

Bidens connata Muhl., called the "Purple-Stemmed Swamp Beggar's Ticks", is extremely variable in all its parts, but chiefly so in the leaf form and length of petiole, and in the awn characters of the akenes. Fernarld,[9] in his review of this species says that it commonly occurs with simple leaves (var. *petiolata* (Nutt.) Farwell), but occasionally it possesses tripartite leaves matching Muhlenberg's original description. Sherff[10] writes of observing with Fernald abundant tripartite-leaved forms of this species, from Cambridge to Winchester, Massachusetts. These were young vigorous plants, 3 dm. high. He also says that in the central United States, tripartite leaves appear only on robust well-developed plants. He extends Fernald's given range, Quebec, Massachusetts, and Michigan southward, to Elgin, Illinois.

Fassett[11] describes six varieties of this species as found in Wisconsin, based mostly on the leaf forms, length of outer involucral bracts, size of akenes and especially on the direction of akenal hairs and awn barbs. Space does not permit discussion of these findings with reference to Iowa, but the form most commonly found and herein described has the simple narrowly margined or distinctly petioled leaves, frequently with lower leaves tripartite in large vigorous plants.

Fassett delimits the varieties of *B. connata* as follows:

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9 Fernald, M. L. *Bidens connata* and Some of its allies. Rhodora 10:197. 1908.

10 Sherff, E. E. Studies in Bidens IV. Bot. Gaz. 64:21. 1917.

11 Fassett, Norman C. *Bidens connata* and its varieties in Wisconsin. Rhodora 30.81-87. 1928.

1. var. *typica*: leaves simple or cleft; winged petioles; outer bracts 1.5 cm. long; akenes not more than 6.5 mm. long, retrorsely barbed except near base.
2. var. *fallax*: an offshoot of var. *typica*; leaves simple, often 3-cleft, petioles winged; outer bracts 3-6 cm. long; akenes as in var. *typica*.
3. var. *petiolata*: middle leaves simple, rarely 2-3-cleft; petioles 7 cm. long, very narrowly margined; inner akenes 7-8 mm. long, retrorsely barbed except sometimes near base.
4. var. *ambiversa*: leaves simple, coarsely dentate to 3-cleft; outer bracts 1-3.5 cm. long, foliaceous; outer akenes 5 mm. long, inner akenes 6-8 mm. long, margins with sparse to copious, mostly antrorse hairs, awns with antrorse or retrorse barbs or intermixed.
5. var. *anomala*: leaves simple, rarely with 2 basal lobes; outer bracts 1-3.5 cm. long, foliaceous; akenes as in var. *ambiversa,* margins and awns antrorsely barbed.
6. var. *pinnata*: lower and middle leaves 3-7-pinnately divided, base of each division narrowed upon the petiole; outer bracts mostly 1-1.5 cm., foliaceous; outer akenes 4.5-5 mm. long, 3-awned, inner akenes 6-7 mm. long, retrorsely barbed.

It grows in swamps and ditches and in low woods, frequently being found associated with *B. cernua,* and *B. comosa.*

Its range in the United States is from New Hampshire, Massachusetts, and Virginia westward to Minnesota and Missouri, being very common in all Mississippi Valley states. In Iowa, it is common to scarce, generally distributed over the state, chiefly in swamps and low moist ground. The writer secured vigorous plants in such moist areas in Muscatine, Scott, and Johnson Counties, these often with the lower leaves tripartite. (Pl. XXII).

It is reported by counties as follows: Cerro Gordo (34), Decatur (14), Emmett (34), Fayette (12, 15), Hamilton (34), Hardin (40), Henry (12), Iowa (57), Johnson (14, 56), Mitchell (59), Story (12, 20), Webster (27), Winnebago (34), Winneshiek (11), and from the state of Iowa (17).

Bidens comosa (Gray) Wiegand.
Bull. Torr. Club 24:436. 1897.

Bidens connata* var. *comosa **A. Gray, Man. 5 ed.:261. 1867.**
Bidens riparia **Greene, Pittonia 4:61. 1901.**
Bidens acuta **Wiegand, Britton, Man. 1001. 1901.**

Plate XXXIX

Stem: 2-10 dm. tall or more, straight, stout, stramineous throughout, touched with purple, branches short and stout, ascending.

Leaves: opposite, simple, lanceolate or elongate elliptic, obtuse or acute, attenuate to a long margined petiole or the upper sessile, connected at base, coarsely serrate, teeth ascending, pale dull green, glabrous except on margins, veins straight and ascending, ending in the teeth or sinuses.

Heads: large 12-15 mm. high, 15 mm. broad, discoid, arranged cymosely on short stout peduncles in upper axils, appearing clustered.

Involucre: outer bracts 6-8, large, erect, spatulate, obtuse, often foliaceous and toothed.

Ray-flowers: wanting.

Disk-flowers: about 4 mm. long, pale greenish or lemon yellow, 4-lobed (occasionally 5-lobed), narrow funnel-form with stamens and style included.

Chaff: slender, acute, yellow-tipped, brown striate, shorter than disk-flower, deciduous with akenes.

Akenes: 7-10 mm. long, 3 mm. broad, cuneate, summit not convex, slightly or scarcely keeled, olive or brown, often minutely dark-dotted, striate, margin not crenulate, mostly retrorsely hispid except toward base.

Pappus: usually 3 straight stout awns $\frac{1}{3}$-$\frac{3}{4}$ as long as akene, equalling or longer than disk-flowers, retrorsely barbed.

Root: annual.

B. comosa is a very characteristic species as it stands in large crowded patches. Its stout straw-colored stem, and short sturdy branches identify it at once. The akene, mostly 3-awned, retrorsely barbed, is unique among American representatives of the genus. The pale leaves, foliaceous involucre of numerous bracts, and the pale yellow 4-lobed disk-flowers are other features that distinguish it from *B. connata,* with which it is frequently confused. The variety *acuta* has the outer bracts acute and not much longer than the inner ones; the akenes of the specimens examined were narrow wedge shaped and had three awns.

This species was not recognized as such by early botanists but was thought to be a variant of *B. connata* Muhl. Gray[12] noted constant

12 Gray, A. A Manual of Botany of Northern United States. Edition 5, 1867.

differences among certain *Bidens* hitherto called *B. connata* Muhl., and separated the variety *comosa* as being a stouter, paler form with leaves commonly all simple, the upper sessile, and with heads larger and with very leafy involucre. In 1897, Wiegand[13] reaffirmed these characters as distinct and constant, and he also observed several features unnoted before. "Convinced that under *B. connata* there were two distinct forms", he erected the new species *B. comosa.* Describing both species and listing their differences, he thus definitely placed *B. comosa* on record as a species.

The habitat of *B. comosa* is always in low moist ground, and in swamps, sandy soils and mud flats along streams; it is frequently found with *B. connata.*

Its distribution in the United States is from Maine to Minnesota, Illinois, and Kentucky, west and southwest. In Iowa it is perhaps as common as *B. connata.* The writer secured plants from swamps and low places in Scott and Muscatine Counties. Herbarium specimens were from the counties of Dallas, Union, Fayette, Clayton, Hardin, Chickasaw, Polk, Floyd, Story, Van Buren, Henry, Appanoose, Decatur, Boone, Marshall and Cedar.

It is reported as common in wet soil in counties as follows: Decatur (12), Fayette (10, 12, 15), Johnson (12, 56), Muscatine (4), Scott (4), Webster (27) and from the state of Iowa (7).

Bidens frondosa L.

Sp. pl. 832. 1753.

Bidens melanocarpa Wieg. Bull. Torr. Club. 26:405. 1899.

Plate XL

Stem: 5-10 dm. tall, slender, bushy-branched, glabrous or slightly hairy, furrowed, reddish in the upper parts.

Leaves: opposite, lower pinnately 5-divided, upper 3-divided, often all 3-divided, divisions distinct and mostly petiolate, lanceolate or the terminal one ovate-lanceolate, acuminate, serrate, with spreading teeth, green both sides, petioles and under surface slightly hairy, thin but not membranous, veins prominent, straight.

Heads: numerous, discoid or rays rudimentary, rather small on long, slender, reddish, axillary branches.

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13 Wiegand, Karl M. A new species of Bidens. Bull. Torr. Bot. Club 24:436-437. 1897.

Involucre: outer bracts 5-8 or more, unequal, spatulate, acute, ciliate toward base, conspicuous and much exceeding the disk, inner bracts brownish, ovate, as long as disk, ciliate toward base, innermost bracts membranaceous with transparent margins.

Ray-flowers: usually none on later heads, small and inconspicuous when found on earlier heads.

Disk-flowers: usually 5-lobed, orange-yellow, funnel-form, narrowed about the middle, stamens exserted.

Chaff: slender, falling with akenes.

Akene: brown, 7-8 mm. long, 4-5 mm. broad, very flat, rugose, contracted at the top, nearly glabrous, one nerved, margins mostly antrorsely hispid except near the top—a somewhat variable character.

Pappus: 2 firm erect diverging awns mostly retrorsely barbed occasionally antrorse, usually more than ½ as long as the akene, longer than disk-flower.

Root: annual, fibrous.

Bidens frondosa L. is a very distinct species, recognized by its 3-5-parted leaves, reddish stems, discoid heads and very conspicuous outer involucral bracts. The trifoliate forms of this species are often called *B. discoidea* (T. & G.) Britton, but the 6-8 large foliaceous bracts (not 4 as in *B. discoidea*), the shorter petioles of the leaflets, the less membranaceous leaves, and the retrorsely barbed awns distinguish it from the latter species. In the herbarium of the State University of Iowa is a delicate immature plant with trifoliate leaves, akenes and awns antrorsely hispid which has been designated as *B. frondosa* L. var. *anomala* Porter. Fernald regards this form as a geographic variety. (Pl. XL).

This species is one of the most common wet-area plants throughout the United States from Ontario to North Carolina westward to Texas and California; it is not reported for New England. In Iowa, it is abundant and conspicuous and is included in the list of troublesome and noxious weeds.

BIDENS VULGATA Greene.

Pittonia 4:72. 1899.

Bidens frondosa var. *puberula* Wieg. Bull. Torr. Club. 26:408. 1899.

Plate XLI

Stem: 0.5-1.5 m. tall, much branched, nearly glabrous.

Leaves: 5-divided, quite uniform except the very uppermost, seg-

ments lanceolate, short stalked, veins straight as in *B. frondosa,* margin serrate with regular sharp or bluntish teeth, nearly glabrous.

Heads: large, 1.5-2.5 cm. broad, on stout peduncles, discoid, rarely radiate.

Involucre: outer bracts 10-15, unequal, usually longer than the disk, ciliate-hispid, inner bracts with abruptly narrowed tips, membranaceous margins, ciliate on tips and along the veins, shorter than disk.

Ray-flowers: rarely present, pale yellow, equalling disk.

Disk-flowers: 5-lobed (occasionally 4-lobed), pale yellow, narrowed about half way, stamens included.

Chaff: slender, about the length of disk flower, acute, deciduous with akenes.

Akenes: large, 7.5-12 mm. long, 4-4.5 mm. wide, brown, obovate or cuneate, very flat, smooth, or often tuberculate-roughened, margins upwardly hispid except near summit.

Pappus: 2 large retrorsely barbed awns, exceeding the disk-flower, half as long as akene, stramineous.

Root: annual, fibrous.

The variety *puberula* Wieg. differs from the species in that the peduncles, leaves, and outer bracts are covered with soft whitish hairs giving a somewhat hoary or grayish appearance, the inner bracts also are pubescent, the leaves are more finely and bluntly serrate.

This species was formerly included with *B. frondosa* L. which it resembles in general appearance. But the akenes are larger, with margins upwardly hispid, the involucre is less conspicuous and is ciliate, the leaves are more uniformly 5-pinnate, with segments short-petioled and margins finely and evenly serrate.

It was first made a variety by Wiegand[14] who in 1899 named it *Bidens frondosa* var. *puberula.* In the same year Greene raised this variety to the rank of a species under the name *B. vulgata.* The var. *puberula* Wieg. is retained in Gray's Manual, 7th edition, used with the species.

Both forms grow abundantly in moist waste places along roadsides, near swamps and lakes, often with *B. frondosa.* In the United States they are distributed from Ontario to Pennsylvania

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14 Wiegand, Karl M. Some species of Bidens. Bull. Torr. Bot. Club 26:399-431. 1899.

and North Carolina westward to Wisconsin, Missouri, and to British Columbia and California, not so common as *B. frondosa*. In Iowa the species is nearly as common as *B. frondosa* and perhaps is frequently called by that name.

Specimens of both the species and the variety were secured by the writer from all territory visited. Near the Inn on Lake West Okoboji, was found an immature but vigorous plant very much resembling the grayish var. *puberula*. The leaves, however, were bipinnately divided and variously lobed. As the writer had no opportunity to return in the later flowering and fruiting season, the status of this plant remains undetermined. Herbarium specimens were from Lee, Muscatine, and Cerro Gordo Counties.

It is reported from the following counties: Dickinson (51), Dubuque (38), Harrison (48), Johnson (56), Mitchell (59), Monona (48) and from the state of Iowa (17, 47, 52).

BIDENS BIPINNATA L.

Sp. pl. 832. 1753.

Bidens Wallichii DC. Prod. 5:598. 1836.

Plate XLII

Stem: 3-15 dm. tall, erect and branching, glabrous, sulcate, striate, obtusely 4-angled, rather slender, greenish.

Leaves: opposite, thin, 1-3 pinnately parted, most often doubly pinnatifid, the segments somewhat lanceolate or ovate wedge-shaped at base, round-lobed and cleft, the basal leaf segments deltoid, the ultimate one lanceolate, incised or lobed, veins prominent and dark, slightly pubescent along margins, petioles long.

Heads: small, on naked slender peduncles, irregularly radiate.

Involucre: outer bracts usually 8, linear-lanceolate, acute, unequal, as long as the rays, at first erect, later spreading, with narrow transparent margins; inner bracts 8, narrower with wide transparent margins, a little longer than outer bracts, hardly as long as the disk.

Ray-flowers: generally 3 or 4, pale yellow, with 4 deep orange colored veins, 2-notched, ovaries awnless.

Disk-flowers: about 20, yellow with prominent orange colored veins, 5-lobed, stamens included.

Chaff: slender, deciduous with akenes.

Akenes: 2 cm. long, including awns, oblong-spindle shape, slightly angled or 4-grooved, nearly twice as long as the awns, antrorsely barbed.

Pappus: 3-4 awns, about ⅔ as long as disk-flowers, stramineous, outer slightly shorter, retrorsely barbed.

Root: annual.

The outstanding features of this rare species are the greenish stem, the 1-3-pinnatifid leaves with rounded lobes, and especially the long slender almost needle-like akenes. One would never confuse it with other species of *Bidens* and in its vegetative phases, it might even escape recognition as a *Bidens*. It flowers and fruits in late summer and through the fall.

Its given distribution is Rhode Island to Florida, westward to Ohio, Nebraska, Arizona, Mexico and tropical America. From New York it is reported as found in various situations, often as a weed, and from Missouri as common in low ground and waste places. Elliott[15] reports it from Carolina as common in dry soil.

In Iowa at least one specimen is known to exist. This plant was collected by Dr. Jesse L. Fults in Lee County, Sept. 4th, 1931 and is in the herbarium of the Iowa State College at Ames. It was loaned to the writer by R. I. Cratty. Only the uppermost parts are preserved. An immature plant found growing near Manhattan on Lake West Okoboji and thought to be *Bidens bipinnata,* was later designated as *B. vulgata* var. *puberula* Wieg. with bipinnate leaves.

Two authors report it from Iowa: H. A. Mueller from Madison County (25), and L. H. Pammel (36).

Bidens Beckii Torr.

Spreng. Neue. Entdeck. 2:135. 1821.

Megalodonta Beckii (Torr.) Greene, Pittonia. 4:271. 1901.
Megalodonta nudata Greene, loc. cit. 1901.

Plate XLIII

Stem: aquatic, submerged and attached to the bottom of pond or lake, usually rising a little above the surface at flowering season, simple or rarely branched, glabrous, slender, flexible, held up by the buoyancy of the water, collapsing when withdrawn.

Leaves: opposite, mostly submerged, dichotomously dissected, sessile, crowded, the few emerged leaves lanceolate, slightly connate, serrate or incised.

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15 Elliott, S. A Sketch of the Botany of South Carolina and Georgia II: 432. 1824.

Heads: solitary, on short terminal peduncles, rising a few inches above the water, occasionally remaining submerged, radiate.

Involucre: bracts yellowish with brown stripes, the 5 outer bracts shorter than the inner.

Ray-flowers: 6-10, golden yellow, oblong.

Disk-flowers: very delicate, hyaline, 5 lobes somewhat spreading, anthers pale, style-branches ending in conical, acute, densely hairy appendages.

Chaff: broader than in other species, deciduous with flowers.

Akene: (Only immature ones secured), narrow-oblong, thick, slightly flattened or nearly terete, truncate at base and summit, entirely glabrous.

Pappus: usually 4 unequal divergent awns, retrorsely hispid all the way when young, barbed only at tips in maturity.

Root: perennial.

This unusual species of *Bidens* was named after Dr. Lewis E. Beck who discovered it in a pond near Schenectady, New York. Dr. E. E. Sherff prefers to maintain the genus name *Megalodonta* Greene, claiming that the very large thick fruit is really not a Bidens feature.

It is the only true hydrophyte of the genus, as well as of the Tribe Heliantheae in North America. The slender, weak stem buoyed up by the water, and the crowded, finely dissected submersed leaves are interesting adaptations to its water environment; both the stem and the aquatic leaves have large air-spaces and very thin epidermis devoid of stomata. In these respects, the species resembles other lake plants such as *Myriophyllum*, *Ceratophyllum*, and *Ranunculus*. The emerged leaves are entire and possess stomata. Sometimes specimens are found entirely submerged, no air leaves being present, the mature inflorescence also entirely covered by the water, and not emerged a few inches as is usually the case. Completely submerged plants with all leaves entire (not dissected) occasionally are found.

What becomes of the mature akenes is not known, nor how distribution from one pond to another is brought about. The supposition, however, is that the fruits may be carried by water birds.

The species is now known to be distributed in American ponds and slow-moving streams from Quebec to New Jersey, Massachusetts and Vermont, westward to Manitoba, Illinois, and Iowa.

Specimens in full flower were secured by the writer in August

and September, from Lake West Okoboji in Dickinson County. The plants shown in Plate XLIII were sent by Dr. G. W. Martin from this same locality near the Iowa Lakeside Laboratory. Other specimens in the herbaria are from Cerro Gordo and other Dickinson County lakes.

It is reported as locally abundant in lakes and ponds in the following counties: Cerro Gordo (34), Dickinson (51, 61), Hamilton (34), Story (12, 20), Wright (34) and from the state of Iowa (1).

Bidens aristosa (Michx.) Britton.
Bull. Torrey Club 20:281. 1893.

Coreopsis aristosa Michx. Fl. Bor. Am. 2:140. 1803.
Coreopsis aristata Muhl. Willd. Sp. Pl. 3:2253. 1804.

Plate XLIV

Stem: 0.3-1 m. tall, much branched, quadrangular, smooth below, pubescent above, sometimes sparingly so.

Leaves: opposite, petioled, 5-7-divided with segments acuminate at both ends, serrate, incised or pinnatifid, veins and midrib reddish, thin and soft, under surface pubescent.

Heads: numerous, small, 2-5 cm. broad, paniculate-corymbose, peduncles long and slender, disk yellow.

Involucre: hemispheric, outer bracts 8-12, spreading, linear-spatulate to oblong, sometimes slightly ciliate or minutely hispid, usually not exceeding the inner bracts, though sometimes longer and foliaceous, inner bracts broader, barely united at the base or distinct, not resin dotted.

Ray-flowers: 6-10, large, golden yellow, entire.

Disk-flowers: yellow, anthers brown, style-branches cuspidate, stamens exserted.

Chaff: slender, longer than disk-flowers, deciduous with akenes.

Akenes: olive-brown, broad-obovate or oblanceolate, flattened parallel with the scales of the involucre, slightly angled, abruptly contracted at summit, sparingly antrorse strigose or hispid-ciliate and scarious, margins thin, crenate or crenulate and antrorsely hispid, often tuberculate.

Pappus: 2 slender awns nearly as long as akene, diverging, stramineous, upwardly, sometimes downwardly barbed, sometimes short or entirely absent, extremely variable.

Root: annual, fibrous.

Variations in this species center about the akene and its awn characters. At least three types of awns are so common as to give rise to the var. *Fritcheri* Fernald having the long awns retrorsely barbed, and var. *mutica* (Gray) Gattinger with awns entirely absent Pl. XLIV.[16] The outer involucral bracts also show variation, being not at all dependably shorter than the inner bracts. Plants from which the drawings and plates were made had outer bracts variously shorter, as long as, or longer than the inner ones. Specimen No. 783171, Missouri Botanical Garden, collected by John Davis near Oakwood, Missouri, has very long foliaceous bracts with smooth surface and margins; the akenes of this plant have scarious crenulate margins and short thick spreading awns.

Perhaps the most reliable floral feature of *B. aristosa* is the scarious margin, antrorsely crenulate and hispid; but even this was found to fail in Specimen No. 777409, Missouri Botanical Garden, and also in a specimen from the herbarium of the Field Columbian Museum, both verified by E. E. Sherff. These have the akene margin merely antrorsely hispid, not scarious nor crenulate, in this respect resembling more the akene of *B. involucrata* (Nutt.) Britton.

Because of the upwardly hispid margins, the species was originally included in the genus *Coreopsis* as *C. aristosa* Michx., but Britton (1893) transferred it to the genus *Bidens* on account of the true awns in some forms.

It thrives in moist soil, swamp, peat bogs and low wet woods, and is perhaps the most delicately beautiful of the Bidens.

It is distributed from Ohio to Michigan, Iowa, Kansas and Texas, very abundant in Missouri and probably native in southern Iowa. The writer secured specimens along the canal near Lake West Okoboji, Dickinson County, and along Duck Creek near Davenport. Herbarium specimens were from Madison, Allamakee, Iowa, and Muscatine Counties. Specimens for verification were from the Missouri Botanical Garden and Field Columbian Museum, verified by E. E. Sherff.

It is reported among the weed flora from the following counties: Benton (12), Muscatine (4, 12), Scott (4), Wapello (36), Marion (36), Polk (36), Decatur (36) and from the state of Iowa (17).

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[16] Fernald, M. L. Some noteworthy varieties of Bidens. Rhodora 15:74-80. 1913.

BIDENS INVOLUCRATA (Nutt.) Britton
Bull. Torr. Club 20:281. 1893.

Coreopsis involucrata Nutt. Journ. Phil. Acad. 7:74. 1834.

Plate XLVI

Stem: 3-10 dm. tall, slender, simple but usually with short lateral branches, quadrangular below, minutely pubescent.

Leaves: opposite, 5-7-pinnately divided, divisions narrow, linear-lanceolate, long acuminate, serrate and incisely toothed.

Heads: several to numerous, somewhat paniculate on slender hirsute peduncles, radiate, 3-5 cm. broad.

Involucre: outer bracts 12-20, linear, acutish, hispid on back and margins, longer than inner bracts which are brown with yellowish tips.

Ray-flowers: usually 8, golden yellow, 2 cm. long.

Disk-flowers: 5-lobed, light yellow, tubular, narrowed abruptly below the middle into a slender tube, stamens exserted.

Chaff: slender, longer than disk-flowers, somewhat acute, deciduous with fruit.

Akene: elliptic obovate to oval, very flat, slightly contracted at the summit, upwardly strigose-ciliate especially on thin scarious margins.

Pappus: 2 very short teeth upwardly barbed or hispid.

Root: annual, fibrous.

B. involucrata, the "Long-bracted Tickseed Sunflower", resembles in appearance both *B. trichosperma* and *B. aristosa,* but is distinguished from them by the larger heads, the more numerous and hispid outer involucral bracts exceeding the disk, the inner bracts yellow-tipped, and upwardly hispid akenes; the segments of the leaves are narrower and more acuminate. The variety *retrorsa* Sherff, examined at the Missouri Botanical Garden, has awns retrorsely barbed and the margin of the akene antrorsely hispid.

It grows abundantly in low grounds and marsh-meadows, coming into bloom in July and lasting through the summer and fall.

It is indigenous to the Mississippi Valley, ranging from Illinois to Kansas, Arkansas and Texas, rarely adventive eastward. In Iowa it is common in the southern and southeastern parts and frequent in northern swampy areas.

R. I. Cratty[17] writes of this species: "This pretty composite is very common in the southern part of the state occurring in large patches in low ground, and is gradually working northward. It is confused with two similar species, *B. trichosperma* and *B. aristosa*, which are comparatively rare in the northeastern section. The mature akene and the bracts furnish the most reliable characters in distinguishing these three species." Thrifty plants of this species were gathered by the writer from low moist places along roadsides and in swamps in Muscatine County. Herbarium specimens were from the following counties: Appanoose, Union, Woodbury, Muscatine, Fremont, Van Buren, Marion, Lucas, Page, Madison, Decatur, Polk, Chickasaw, Story, Wapello, Boone, Marshall, Emmett and Jasper.

It is reported for Iowa as follows: Decatur (12), Johnson (56), Scott (4), Webster (27) and from the state of Iowa (17).

BIDENS TRICHOSPERMA (Michx.) Britton.
Bull. Torr. Club 20:281. 1893.

Bidens trichosperma var. *tenuiloba* Britton Bull. Torr. Club 20:281. 1893.
Coreopsis trichosperma Michx. Fl. Bot. Am. 2:139. 1803.
Coreopsis aurea Lindl. Bot. Reg. 1228. 1829.
Coreopsis trichosperma var. *tenuiloba* A. Gray, Syn. Fl. 12:295. 1884.
Diodonta coronata Nutt. Trans. Am. Phil. Soc. 7:360. 1841.

Plate XLVII

Stem: 6-15 dm. tall, slender, obscurely quadrangular, glabrous, much branched toward the top.

Leaves: opposite, somewhat pinnately divided into 4-8 distant segments, narrowly lanceolate, acute or acuminate, segments remotely cut-serrate or incised, the upper often merely 3-cleft and nearly sessile, thin.

Heads: 4-5 cm. broad, sometimes more, erect, long-peduncled, paniculately corymbose, radiate.

Involucre: outer bracts 8, linear-spatulate, obtuse, entire, rarely ciliate, fringed with small setaceous teeth equalling or shorter than the disk and about the length of the inner ones; inner 8 bracts entire, striate, colored.

Ray-flowers: several, usually 8, bright yellow, 1.2-2.5 cm. long, entire or bidentulate at apex.

[17] Cratty, R. I. Iowa Plant Notes IV. Ia. Acad. Sci. 37:89. 1930.

Disk-flowers: 5-lobed, bright yellow, stamens brownish, exserted.

Chaff: about as long or slightly longer than disk-flower, slender, acute, deciduous with akenes.

Akenes: 5-7 mm. long, narrowly cuneate to oblong wedge-form with prominent ridges, narrowed at summit, minutely or sparsely hairy, upwardly strigose-ciliate above.

Pappus: 2 subulate hispid teeth sometimes developed into short stout erect awns upwardly barbed, quite variable and occasionally obsolete, short intermediate teeth sometimes extend from the ridges, all teeth then being connected. The var. *tenuiloba* Gray has smaller akenes with spreading teeth.

Root: annual.

Because of the prominent ridges of the wedge-shape akenes, the variable awn structures, and the upward hispidity, *B. trichosperma* was formerly placed in the genus *Coreopsis*. In 1893, Britton transferred it to the genus *Bidens* on the ground that it possessed real awns. Even so, the fact of the prominent ridges and the frequently obsolete teeth or awns makes identification a difficult process. To the casual observer *B. trichosperma, B. aristosa, B. involucrata* and *B. coronata* resemble one another, and only by patient persistent examination in field and herbarium and with the lens can the reliable distinctions be brought out.

Herbarium specimens from the Missouri Botanical Garden and from the Field Museum, verified by Dr. E. E. Sherff were used for comparison in this study. Also specimens from the herbarium of the University of Wisconsin were loaned by Dr. N. C. Fassett.

Like the other "Tickseed Sunflowers", *B. trichosperma* grows in swamps, peat bogs and other wet places. It comes into bloom in June, continuing through the summer and fall until frost.

Its range is from New York, southward to Virginia, North Carolina, Georgia, westward to Minnesota, Illinois, Kentucky and Nebraska. In Iowa, it occurs in all peat bogs of many of the northern counties. "It is so characteristic that without the presence of any other plants, one is certain peat occurs." (Pammel, 34). Specimens of this species are to be found near Wilton, and also at the edge of the woods at Wild Cat Den. Herbarium specimens were from Cerro Gordo, Van Buren, Lee and Hancock Counties.

It is reported from the following counties: Cerro Gordo (34), Hardin (40), Mitchell (59), Scott (4), Webster (27), Winnebago (34) and from the state of Iowa (17).

BIDENS LAEVIS ((L.) BSP.
Prel. Cat. N. Y. 29. 1888.

Helianthus laevis L. Sp. Pl. 906. 1753.
Coreopsis bidens Walt. Fl. Car. 215. 1788.
Bidens chrysanthemoides Michx. Fl. Bor. Am. 2:136. 1803.
Bidens quadriaristata DC. Prod. 5:595. 1836.

Specimens of this species examined and compared with Iowa plants were from the herbaria of the Missouri Botanical Garden and the Field Museum, Chicago, verified by E. E. Sherff. A typical specimen from California (Pl. XXXIII) resembles the large forms of *B. cernua* in some essential characters, but it was found also to differ in the following respects from them and from other Iowa plants listed under the name *B. laevis*:

Stem: larger, 5-10 dm. tall, erect, more slender in general form, often purple tinged, branches above the middle of the stem, ascending.

Leaves: smaller, elliptic-lanceolate, short-acuminate, somewhat contracted toward the sessile or connate-perfoliate base, serrate, with teeth small and inconspicuous, glabrous, not much paler beneath.

Heads: medium, mostly erect on long slender peduncles, slightly nodding in fruit.

Involucre: bracts about 8, sub-equal, rarely longer than the disk, glabrous or slightly ciliate, margins conspicuously wavy, inner bracts oval, stramineous, purple-tipped, about equal to the disk.

Ray-flowers: large, oval with rounded apex, bright yellow.

Disk-flowers: large, lobes spreading, bright yellow, tube contracted, longer than upper part, stamens exserted.

Chaff: purple-tipped, concave, membranaceous, as long as disk-flowers.

Akenes: 7-9 mm. long, greenish brown, cuneate, convex at summit, slightly carinate, not tuberculate, margin strongly crenate and retrorsely hispid.

Pappus: 2-4 awns, somewhat spreading-erect, more than one half the length of akene, retrorsely barbed.

Difference of opinion exists regarding the distribution of this species. MacMillan [18] gives to it the same wide range as that of *B. cernua*; Britton and brown[19] report it from Quebec to Ontario, Min-

[18] MacMillan, Conway. Metaspermae of the Minnesota Valley. Geol. & Nat'l. Hist. Sur. Minn. Bot. Ser. 1:499. 1892.

[19] Britton, N. L. & B. L. Brown. Illustrated Flora of North America. 3:436. 1898.

nesota, south to Florida, Louisiana, Mexico and southern California; Wiegand[20] says that it is really a coast plant, and that except in one or two instances, seems never to have penetrated far inland; Sherff[21] confines it to the central southern coast areas; in Gray's Manual, 7th edition, its range is given as near the coast from Massachusetts southwest, also in New York.

No plants from the field nor any Iowa specimens from the herbaria conform to the authentic specimens examined.

The following authors report it as frequent throughout Iowa in wet places, such as swamps, margins of pools and river banks: Arthur (1), Cratty (6), Fink (10), Fitzpatrick (12, 13), Geiser (15), Greene (17), Hitchcock (20), Oleson and Somes (27), Pammel (30), Peck (40), Shimek (15), Somes (56).

The writer assumes that these reported plants are the larger forms *B. cernua* with heads erect just coming into flower, as suggested by Wiegand.

BIDENS DISCOIDEA (T. & G.) Britton.

Bull. Torr. Bot. Club 20:281. 1893.

Coreopsis discoidea T. & G. Fl. N. Am. 2:339. 1842.

The specimens used in the study of the species *B. discoidea* were from the herbariam of the Field Museum and from the Missouri Botanical Garden, verified by E. E. Sherff.

The writer secured plants along the canal near Lake West Okoboji which seemed to conform to the type, particularly in the akenes with the upward hispidity and antrorsely barbed awns. This view was later abandoned, the plants being designated as the smooth 3-divided leaf form of *B. frondosa* L. with antrorse awn character, var. *anomala* Porter.

The most reliable characters distinguishing the species from *B. frondosa* are found in the smaller thinner 3-foliate leaves with long petioled terminal segment, the smaller heads on short peduncles, the four bracts, usually not foliaceous, and the antrorse hispidity on the small narrow akenes and two small awns. Additional points of distinction are listed in the following description:

Stem: slender to robust, reddish above, freely branched.

Leaves: 3-divided, the lateral segments either sessile or slender-

20 Wiegand, Karl M. Some Species of Bidens. Bull. Torr. Bot. Club 26:399-401. 1899.

21 Sherff, E. E. Studies in Bidens III. Bot. Gaz. 61:495-506. 1916.

petioled, coarsely serrate, the teeth mucronulate, long acuminate, membranaceous, glabrous; both lower and upper leaves may be undivided.

Heads: small, discoid, numerous, paniculate-corymbose at ends of very short slender peduncles.

Involucre: outer bracts 3-5, usually 4, linear-spatulate, obtuse, usually longer than the disk but not foliaceous, smooth, not ciliate toward base; inner bracts equalling the disk.

Disk-flowers: orange, 5-lobed, small, equalling or smaller than the awns, stamens slightly exserted.

Chaff: slender, deciduous with akenes.

Akenes: small, 4-5 mm. long, black, narrowly cuneate to oblong, slightly contracted at summit, upwardly strigose, tuberculate or almost smooth.

Pappus: 2 erect stout awns ¼-½ as long as akene, antrorsely hispid, occasionally retrorse.

Because of the antrorse hispidity of the akene and awns, *B. discoidea* was originally classed in the genus *Coreopsis*. Britton, in 1893, transferred it to the genus *Bidens* because it possessed true awns.

Like *Bidens frondosa, B. discoidea* grows in low ground, on wet banks, swamps and in old sphagnum bogs. It blooms from August to October.

Its range is said to be not so wide as that of *B. frondosa*. It is common in northern New York to Virginia, south to Carolina, westward to Michigan, Ohio, Louisiana, and Texas, less common in its eastern range and rare in New England. Dr. E. E. Sherff and others assert that the species does not exist in Iowa and that the 3-foliate forms so commonly found are variations of *B. frondosa.*

It is reported in Iowa as common in eastern and southern parts (Pammel, 36) and from the state of Iowa (17, 34, 36).

BIDENS CORONATA (L.) Fischer.

Steud. Nom. Ed. 2:202. 1840.

Coreopsis coronata L. Sp. pl. 2 ed. 1281. 1763.
Coreopsis aurea Ait. Hort. Kew. 3:252. 1789.

Bidens coronata (L.) Fischer is a confusing species seemingly on the border line between *Bidens* and *Coreopsis*. The specimens examined at the Missouri Botanical Garden and the Field Museum,

verified by E. E. Sherff, possessed the following distinctive characters:

Stem: 3-9 dm. tall, erect, slender, glabrous, except near base, diffusely branched.

Leaves: opposite, simple, or 3-7 divided, lateral divisions incised or lobed, small, oblong, flaccid-hairy, on slender petioles.

Heads: 2.5-5 cm. broad, numerous, on slender peduncles in loose terminal panicles.

Involucre: outer bracts linear, spatulate, equalling the disk, slightly shorter than the inner bracts, which are very dark and punctate.

Ray-flowers: 6-10, 1-3 cm. long, golden yellow, obtuse or 5-lobed, often with purple spot at base.

Disk-flowers: numerous, 5-lobed, yellow, narrowed about the middle, stamens exserted, anthers dark.

Akene: 3-4.5 mm. long, flat, one-nerved, broadly cuneate, glabrous or slightly upward-pubescent, not much incurved at top, very narrowly winged.

Pappus: 2 (sometimes 3), teeth blunt.

Root: biennial (Elliott).

Sherff[22] makes the statement that Britton and not Fischer transferred this species to the genus *Bidens*. He says further that Britton, at the time of transferring several species of *Coreopsis* to *Bidens*, assumed that this species had already been removed by Fischer (Steud. Nom. ed. 2:202. 1840). Britton (1893) treated it as a *Bidens* because of its true though blunt awns.

It grows in wet soil, coming into bloom in August and lasting through September.

In the United States, it ranges from Virginia to Florida and Alabama. Dr. N. C. Fassett reports it from Wisconsin. It is not included in the area covered by Gray's Manual, 7th edition, nor in Iowa.

It is reported, erroneously, without a doubt, from the counties of Boone (8), Scott (4), Iowa (36), Cerro Gordo (34), Worth (34), Emmett (34) and from the state of Iowa (17).

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22 Sherff, E. E. Studies in Bidens I. Bot. Gaz. 56: 495. 1913.

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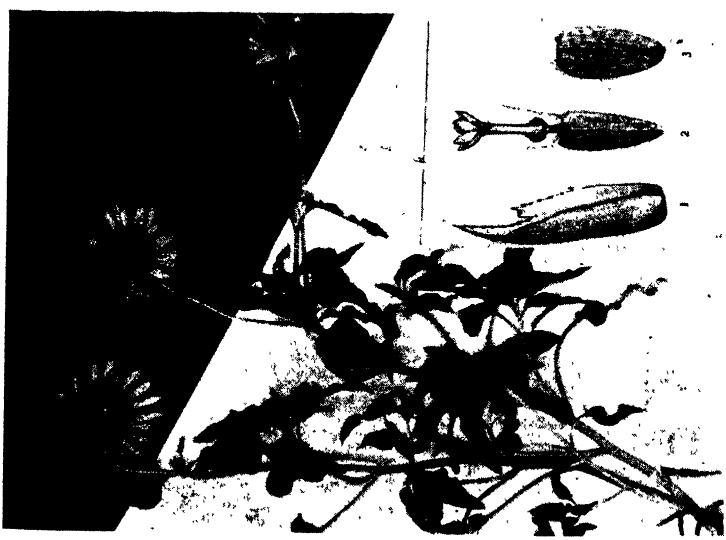


Plate XXIV
HELIANTHUS PETIOLARIS Nutt. Habit; chaff; disk-flower and akene; akene, nearly mature.

Plate XXV
HELIANTHUS SCABERRIMUS Ell. Habit; involucral bract; chaff; disk-flower and akene.

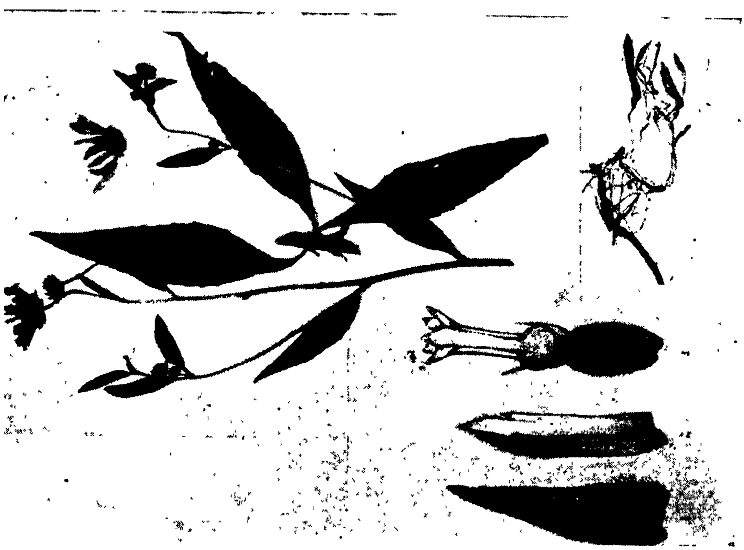


Plate XXVI
HELIANTHUS LAETIFLORUS Pers. Habit; involucral bract; chaff; disk-flower and akene; root and tubers.

Plate XXVII
HELIANTHUS OCCIDENTALIS Ridd. Habit; involucral bract; chaff; disk-flower and akene.

Plate XXVIII
HELIANTHUS MOLLIS Lam. Inflorescence; ray flower; disk-flower and akene; chaff; involucral bract.

Plate XXIX
HELIANTHUS GIGANTEUS L. Habit; involucral bract; chaff; disk-flower and akene.

Plate XXX
HELIANTHUS MAXIMILIAMI Schrad. Habit, showing crown bud (a) and portion of root; involucral bract; chaff; disk-flower and akene.

Plate XXXI
HELIANTHUS HIRSUTUS Raf. Habit; involucral bract; chaff; disk-flower and akene.

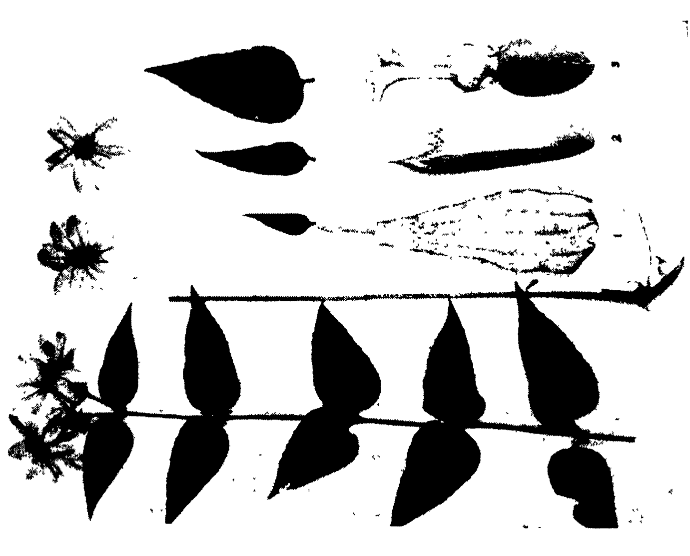


Plate XXXII
HELIANTHUS DIVARICATUS L. Habit; involucral bract; chaff; disk-flower and akene; root.

Plate XXXIII
HELIANTHUS STRUMOSUS L. Habit; involucral bract; chaff; disk-flower and akene; root.

Plate XXXIV
HELIANTHUS DECAPETALUS L. Habit; involucral bract; chaff; disk-flower and akene.

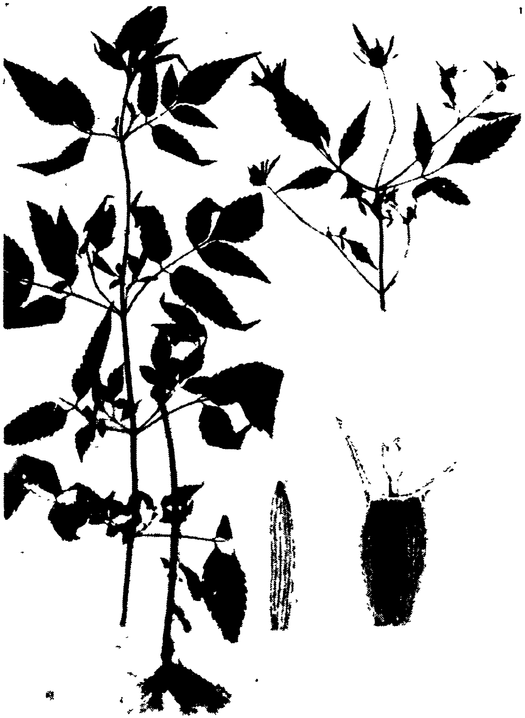
Plate XXXV
HELIANTHUS TRACHELIIFOLIUS Mill. Habit; involucral bract; chaff; disk-flower and akene; root and branching rhizomes.

Plate XXXVI
HELIANTHUS DORONICOIDES Lam. Habit; involucral bract; chaff; disk-flower and akene.

Plate XXXVII
COREOPSIS PALMATA Nutt. Habit; disk-flower; mature akene; outer involucral bract; inner involucral bract; chaff.

Plate XXXVIII
BIDENS CONNATA Muhl. Habit; disk-flower and akene; mature akene; outer involucral bract; inner involucral bracts; tripartite leaf.

Plate XXXIX
BIDENS COMOSA (Gray) Wiegand. Habit; inner involucral bracts; disk-flower and akene.



XL
BIDENS FRONDOSA L. Habit; inner involucral bract; disk-flower and akene.

Plate XLI
BIDENS VULGATA Greene. Habit; inner involucral bracts; disk-flower and akene.

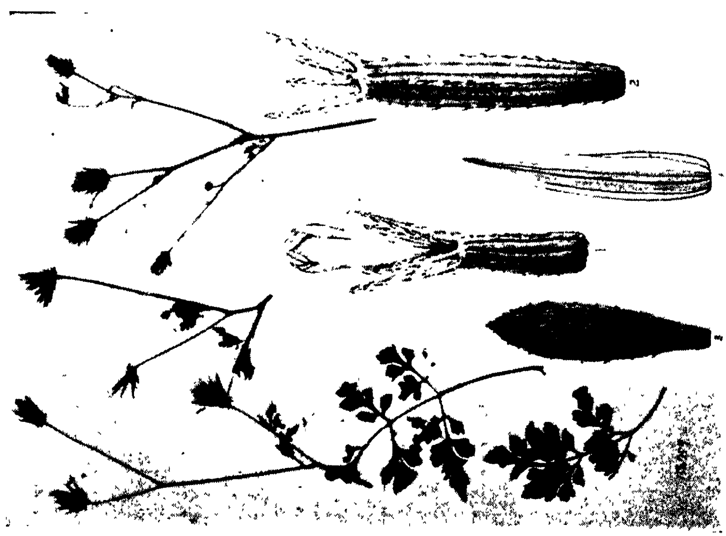


Plate XLII
BIDENS BIPINNATA L. Habit; disk-flower and akene; mature akene; outer involucral bract; inner involucral bract.

Plate XLIII
BIDENS BECKII Torr. Habit; inner involucral bract; disk-flower; immature akene.

Plate XLIV
BIDENS ARISTOSA (((Michx.) Britton. Habit; BIDENS ARISTOSA (Michx.) Britton. Habit; disk-flower; akene; outer involucral bracts; inner

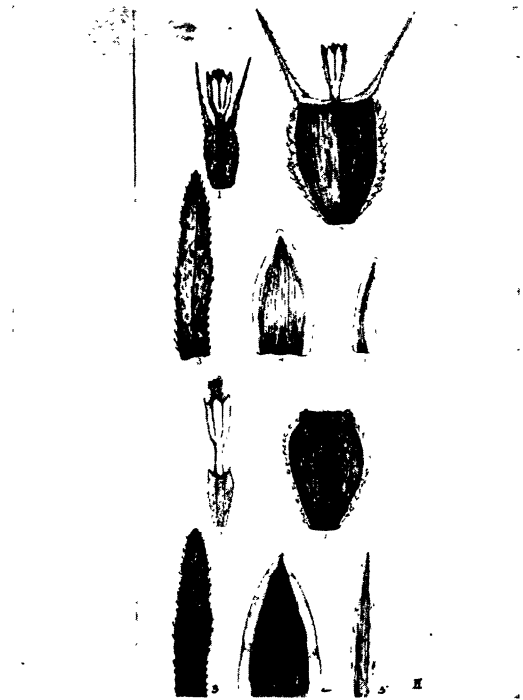


Plate XLV
I. BIDENS ARISTOSA var. FRITCHERI Fernald (above). II. BIDENS ARISTOSA var. MUTICA Gattinger (below).

Plate XLVI
BIDENS INVOLUCRATA Nutt.) Britton. Habit; disk-flower; akene; outer involucral bract; inner involucral bracts.

Plate XLVII
BIDENS TRICHOSPERMA (Michx.) Britton. Habit; disk-flower with sterile akene; disk-flower with fertile akene; outer involucral bract; inner involucral bracts.

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The Prairie Du Chien Problem

by

Elliot H. Powers

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INTRODUCTION

THE PROBLEM

The Prairie du Chien [1] sediments of the Upper Mississippi Valley have been ranked in classification from a formation consisting of three members to two formations of separate systems. The problem involves the relations of the lithologic units, the classification into stratigraphic units, and the application of stratigraphic names. Trowbridge and Atwater [2] have stated the problems and reviewed the complex history of classification and nomenclature of these sediments. Although the main conçern of the writer is the solution of the problems brought out by Trowbridge and Atwater, it is necessary to repeat some of their work and of course to carry it farther.

THE INVESTIGATION

Numerous representative exposures of the Prairie du Chien (see Plate 48) were studied and described in detail. Approximately 1,000 samples of the sediments were collected from chosen beds for investigation in the sedimentation laboratories. Available well data in Iowa, Wisconsin, and Illinois were utilized in determining the subsurface distribution and thickness of the lithologic units, and of the entire Prairie du Chien. Paleontological evidences, in so far as they are known to the writer, were considered, and were compared with physical evidences; however, no additional work was done by the writer on the paleontology of the Prairie du Chien in this approach to the problem.

ACKNOWLEDGMENTS

The writer expresses his indebtedness to Dr. A. C. Trowbridge, who directed the field work and who had general supervision in the preparation of the report. He appreciates the direction of Dr. A. C. Tester in the laboratory investigations, and his aid in incorporating the results in the report. Credit is given to the Iowa State Planning Board, Project 1044-C, for supplying subsurface data on the Prairie du Chien of Iowa.

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1 Bain, H. F. Zinc and lead deposits of the Upper Mississippi Valley. U. S. Geol. Surv. Bull. 294: 17-19. 1906.

2 Trowbridge, A. C. and G. I. Atwater. Stratigraphic problems in the Upper Mississippi Valley. Bull. Geol. Soc. Am. 45: 75-77. 1934.

HISTORY OF NOMENCLATURE

Only the literature dealing with the original nomenclature of the Prairie du Chien sediments, and with the present usage of stratigraphers in the Upper Mississippi Valley is reviewed here.

A first attempt at classification was made by Owen,[3] in 1840, when he applied the term Lower Magnesian limestone to a portion of the old division, "Primitive limestone." In a report of 1873 on the geology of the Minnesota River valley, Winchell[4] adopted the "Lower Magnesian formation" expressly for the Saint Lawrence dolomite, the Jordan sandstone, and his proposed Shakopee dolomite (member). Beds of dolomite and sandstone exposed in a quarry and in natural exposures at Shakopee, Scott County, Minnesota, and which lie stratigraphically above the Jordan sandstone and below the Saint Peter sandstone, were chosen as the type section of the Shakopee member. It is clear that the Saint Lawrence dolomite and Jordan sandstone were correctly identified in the Minnesota River valley, and that all the beds between the Jordan and Saint Peter sandstones at Kasota, Ottawa, and Mankato were ascribed to the Shakopee.

At and near New Richmond and Jewetts, on Willow River, Wisconsin, there are isolated exposures of sandstone beds, 5 to 15 feet in thickness. They are associated with beds of dolomite below and above, though rarely more than 10 feet are exposed in any section. Wooster[5] proposed the term New Richmond for the sandstone which he described as a distinct though lenticular unit separating the lower and upper dolomite units of the "Lower Magnesian series." To the dolomite above, he applied the term "Willow River Beds." This term was used for the beds of dolomite lying above the New Richmond sandstone and below the Saint Peter sandstone, and all dolomite beds in that stratigraphic position on Willow River were assigned as the type sections. From the dam, one mile above Burkhardt, to Willow River Falls at Burkhardt, there is an almost complete exposure of the "Lower Magnesian series," beginning at the top and extending to within 10 to 20 feet of the base. Wooster considered "the exposures at Willow River Falls and vicinity — [as] — the type of all,"[6] however, he did not distinguish the

3 Owen, D. D. House Doc., Exec. Doc. no. 239, 26th Cong., first session: 17. 1840.

4 Winchell, N. H. Geology of the Minnesota valley. Minn. Geol. and Nat. Hist. Surv. 2nd Ann. Rept.: 138-147. 1874.

5 Wooster, L. C. Geology of the lower Saint Croix district. Geology of Wisconsin 4: 106, 123-129. 1882.

6 *Op. cit.*, p. 125.

"Lower Magnesian proper," the "New Richmond sandstone," and the "Willow River Beds" in that section.

McGee[7] completed a report in 1888 on northeastern Iowa, in which he expressed the belief that the New Richmond and Shakopee (Winchell, 1886) have a gradual transition into the Saint Peter sandstone without unconformity and included them in the base of the Saint Peter for this area only. He intended the proposed geographic term Oneota for the massive beds of dolomite exposed along the bluffs of Oneota River (now Upper Iowa River), and as the equivalent of Irving's Main Body of limestone, Wooster's Lower Magnesian proper, and Upham's Shakopee B limestone. The thickness of 200-300 feet ascribed to the beds between the "Potsdam sandstone" and the New Richmond sandstone in northeastern Iowa is inaccurate and misleading, because the average thickness in that area is 150-175 feet.

The geographic term "Prairie du Chien formation" was proposed by Bain,[8] in 1906, for "(*a*) a dolomite at the base, 200 to 225 feet thick; (*b*) a sandstone in the middle, 15 to 130 feet thick, increasing to the southwest under cover; (*c*) a second dolomite at the top, approximately 40 feet in thickness. These are known, respectively, as the Oneota, New Richmond, and Shakopee or Willow River."

A different trend in the stratigraphy of the lower Paleozoics was started in 1911 by Ulrich,[9] who promoted Broadhead's[10] "Ozark series" to the rank of a system for the deposits in the Ozark region younger than the Elvins formation and older than the Yellville dolomite of northern Arkansas. This proposed system was thought to be represented in the Upper Mississippi Valley by the "(1) Mendota, (2) Jordan (Madison sandstone of Wisconsin), (3) Oneota dolomite, and (4) Shakopee dolomite, with the New Richmond sandstone perhaps an introductory phase of the Shakopee."[11] Dana's[12] term "Canadian system" was revived for a system of deposits "younger than — [the Powell dolomite] — of Missouri and the Shakopee and older than the first sandstone and limestone (Ev-

7 McGee, W. J. Pleistocene history of northeastern Iowa. U. S. Geol. Surv., 11th Ann. Rept. pt. 1: 331-333. 1891.

8 *Op. cit.*

9 Ulrich, E. O. Revision of the Paleozoic systems. Bull. Geol. Soc. Am. 22: 640-641. 1911.

10 Broadhead, G. C. The Ozark series. Am. Geol. 8: 33-35. 1891.

11 *Op. cit.*

12 Dana, J. D. Reasons for some of the changes in the subdivisions of geological time in the new edition of Dana's Manual of Geology. Am. Jour. Sci. 8: 214. 1874.

erton) of the Saint Peter series in northern Arkansas."[13] Under this definition the Canadian system was not represented in the Upper Mississippi Valley. In 1914, Ulrich, through Walcott,[14] shifted the Shakopee to the Upper Canadian and placed the Oneota in the Upper Ozarkian.

Both Ulrich[15] and Sardeson[16] believed the New Richmond sandstone on Minnesota River and at Burkhardt, Wisconsin, not to be a distinct stratigraphic unit but to represent sandstone lenses within the upper part of the Oneota or the lower part of the Shakopee and not to be found between them in other sections. At the same time Ulrich gave physical and paleontological evidences for his classification of the Oneota as the Upper Ozarkian and the Shakopee as Upper Canadian, with the Lower and Middle Canadian series missing between them. He purposely avoided use of a formation or series name to include the Oneota and Shakopee, because that was not in harmony with his proposal to place the two in different systems.

Thwaites[17] seemed hesitant, in 1927, to recognize the New Richmond as a formation of equal rank with the Oneota and Shakopee formations of his Prairie du Chien group because he was not able to recognize it in all well sections of northern Illinois.

The most recent publication of the Iowa Geological Survey[18] retains the original classification of the Prairie du Chien of Bain (1906). Needham,[19] in 1932, adopted the "Prairie du Chien series" consisting of the Oneota, New Richmond, and Shakopee formations. A generalized geological column agreed upon for the Wisconsin Survey[20] contains the Oneota and Shakopee formations, which, combined, are equivalent to the "Lower Magnesian" dolomite. In the same year, Minnesota geologists agreed upon a generalized classification in which occurs the "Prairie du Chien (Lower Mag-

13 Ulrich, E. O. *Op. cit.* 647.

14 Walcott, C. D. Cambrian geology and paleontology. Smith. Misc. Coll. 57: 353. 1914.

15 Ulrich, E. O. Notes on new names in table of Paleozoic formations in Wisconsin. Trans. Wisconsin Acad. Sci. Arts and Letters 21: 83, 100-104. 1924.

16 Sardeson, F. W. Type outcrops of Minnesota River valley. Pan-Am. Geologist. 41: 115. 1924.

17 Thwaites, F. T. Stratigraphy and geologic structure of northern Illinois. Ill. Geol. Surv. Rept. of Investigations, no. 13: 21-24. 1927.

18 Norton, W. H. Deep wells of Iowa. Iowa Geol. Surv. 33: 24. 1928.

19 Needham, C. E. Contributions to the subsurface geology of northern Illinois, between the outcrops of the Saint Peter and Dresbach formations, with special reference to the New Richmond formation. Unpublished doctor's thesis, Northwestern University library. 1932.

20 Martin, Lawrence. The physical geography of Wisconsin. (Geologic column by W. H. Twenhofel, F. T. Thwaites, G. O. Raasch and R. R. Schrock). Wis. Geol. and Nat. Hist. Surv. Bull. 36, 2nd ed.: 4. 1932.

nesian) group'' consisting of the Oneota and Shakopee formations.

Trowbridge and Atwater,[21] following a review of literature dealing with these sediments, concluded tentatively that the Prairie du Chien should be recognized as a formation consisting of three members. For the lower dolomite and middle sandstone members, the terms Oneota and New Richmond, respectively, were applied. It was thought that any evidence contrary to the belief that the beds at Shakopee are of Oneota age is paleontological. These authors were not in favor of retaining the term Shakopee for the upper dolomite unit of the Prairie du Chien if the beds at Shakopee are not to be included in it, but hesitated to return to the usage of Wooster's Willow River beds until the age of the beds at Shakopee could be conclusively determined. In support of the belief that the Shakopee type section is of Oneota age, Couser [22] presented a generalized well log obtained from H. H. Strunk at Shakopee and applied stratigraphic divisions according to the then accepted classification as follows:

LOG OF WELL AT CITY WATER WORKS IN SHAKOPEE. ELEVATION OF WELL SITE, 725 FEET

Rock	Thickness	Depth
Shakopee [?] and Oneota	58	58
Jordan	146	204
St. Lawrence and Franconia sandy limestone	133	337
Dresbach		
Galesville (?) white sandstone	95	432
Eau Claire, sandstone and sandy limestone	173	605
Mt. Simon, white and red sandstone	98	703
Very red at bottom—Red Clastics (?)		

He was not able to find in the field and laboratory any physical distinction between the beds exposed at Shakopee and the Oneota of other sections.

Within the year, Stauffer [23] returned to Winchell's interpretation of 1886 concerning the section at Shakopee in that he believed the beds exposed belong to the upper member of the old ''Lower Magnesian formation.'' He presented a generalized description of beds down to Minnesota River level and supplemented his interpretation

21 *Op. cit.*: 71-73.

22 Couser, C. W. Unpublished Thesis, Univ. of Iowa library. — Since Couser's paper was first written, he has modified this section according to: "Paleozoic stratigraphy and structure in the Minnesota River valley." Univ. Iowa Studies Nat. Hist. 16: 451-472. 1935.

23 Stauffer, C. R. Type Paleozoic sections in the Minnesota valley. Jour. Geol. 42: 347. 1934.

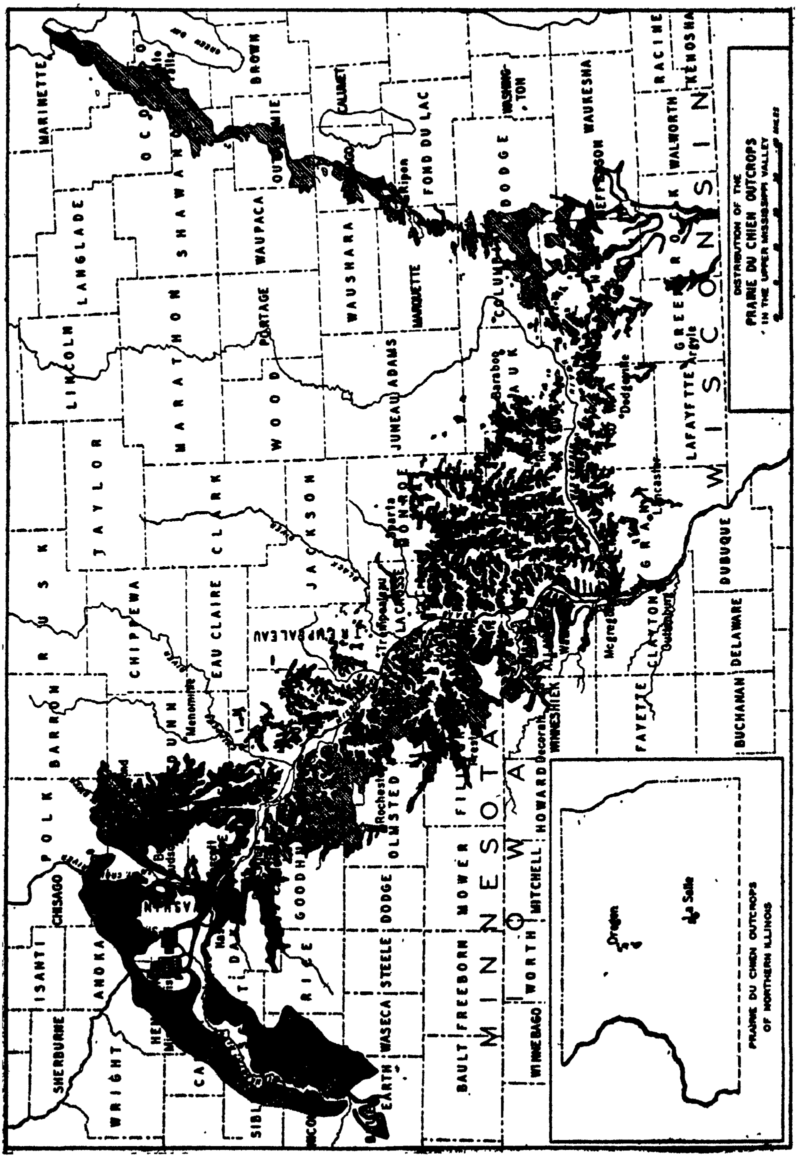
DISTRIBUTION OF THE PRAIRIE DU CHIEN OUTCROPS IN THE UPPER MISSISSIPPI VALLEY
PRAIRIE DU CHIEN OUTCROPS OF NORTHERN ILLINOIS
WISCONSIN
MINNESOTA
IOWA

Plate 48

of the local water works well log for beds below river level. Below 38 feet of "Shakopee dolomite" and 2 feet of "New Richmond (?) sandstone" described from exposures above river level he believed the following rocks to be shown by the well log:

Oneota dolomite
No. 7. Dolomite, gray to drab ---------- 31 feet
No. 6. Sand and sandy gray dolomite, water-bearing and reported as sandstone ---------- 35 feet
Jordan sandstone
No. 5. Sandstone, buff to white ---------- 100 feet
St. Lawrence formation
No. 4. Dolomites, arenaceous, with shales and sandstone ---------- 144 feet
Franconia sandstone
No. 3. Sandstone, white ---------- 95 feet
Dresbach formation
No. 2. Sandstones, gray, and gray shales ---------- 173 feet
Hinckley sandstone
No. 1. Sandstone, white to red. To the bottom of hole, 22 feet A. T. -- 98 feet

In addition to species of fossils already described by Sardeson from the Shakopee section, he reported a diminutive Molluscan fauna from the oolitic chert and several trilobites all of which are yet unidentified.

DISTRIBUTION

Shaded areas on Plate 48 indicate the location and distribution of outcrops of the Prairie du Chien formation. Formation boundaries were traced from geologic maps of Iowa, Minnesota, Wisconsin, and Illinois. The irregular outcrops of northeastern Iowa, southeastern Minnesota and southwestern Wisconsin generally coincide with the Driftless Area. Possibilities of exposure are reduced by glacial drift in the region northwest of the Driftless Area and in eastern Wisconsin. In Illinois, small inliers occur at Oregon and La Salle.

THICKNESS

In addition to thicknesses of the Prairie du Chien measured by the writer in exposures, a large number have been obtained from reports of the Iowa, Minnesota, Wisconsin, and Illinois geological surveys, and other geological reports. A few were furnished by F. T. Thwaites for western and southwestern Wisconsin, and several for Iowa were furnished by the Iowa State Planning Board.

An isopach map of the Prairie du Chien (Pl. 49), constructed

from measured thicknesses of exposures and in well records, demonstrates an increase in thickness away from the outcrop as the formation passes beneath younger Paleozoic sediments. A local isopach high, whose axis trends slightly east of north through the Twin Cities, and one east of New Richmond, Wisconsin, coincide in a general way with two minor synclines shown by Trowbridge [24] in 1934. Both the isopach highs and the synclines converge southward to a major isopach high and syncline, respectively, whose axes generally coincide. The line of maximum thickness continues southward into Iowa, east of Des Moines, and thence southeast between Centerville and Bloomfield, whereas the structural basin [25] extends southwest from Des Moines toward Clarinda. The general coincidence of isopach highs with synclines suggests that the latter were basins for Prairie du Chien deposition. The fact that regional structure in Iowa, Minnesota, and Wisconsin is reflected in both the lower and upper beds of the Prairie du Chien, and in the underlying and overlying formations as well, indicates that the basin subsided with deposition during Prairie du Chien time. The syncline in southwestern Iowa seems to be unrelated to changes in thickness of the Prairie du Chien. In the region of the La Salle anticline, Illinois, there is an increase in thickness of the Prairie du Chien. The direct relation of subsidence of the basin to deposition, suggested for the rest of the Upper Mississippi Valley, probably existed in this area also, but the La Salle anticline originated after deposition of the Prairie du Chien. There is no evidence at hand to show any relation of such minor structures as at Ellsworth, Wisconsin, to deposition.

Irregularities in the thickness of the Prairie du Chien in southern and southeastern Wisconsin, extreme eastern Iowa, and in northern Illinois are due principally to post Prairie du Chien and pre-Saint Peter erosion; in fact, the entire formation was removed in much of southeastern Wisconsin and in a portion of north central Illinois. Configuration of isopach lines in this area might be considered in reconstructing pre-Saint Peter topography in that the location of a possible major system of drainage to the northeast toward Lake Michigan is suggested. In the vicinity of La Salle, Illinois, the

24 Trowbridge, A. C. Upper Mississippi Valley structure. Bull. Geol. Soc. Am. 45: 522-528, fig. 1. 1934.

25 Norton, W. H. Deep wells of Iowa. Iowa Geol. Surv. 33, Pl. I, 1928; Structural contour maps of Iowa: furnished by Iowa State Planning Board, 1934.

maximum thickness of the Prairie du Chien is near the axis of the La Salle anticline.

The upper dolomite member of the formation, by virtue of its superposition, was subjected to more pre-Saint Peter erosion than the middle and lower members, except where the entire upper member was removed. An isopach map of the upper member would thus show much greater irregularity than similar maps of the other two members. In exposures and well records, where the three members of the Prairie du Chien have been distinguished, there is an indication that the variation in original thickness of both the lower and middle members is directly proportional to variation in the original thickness of the entire formation. The difficulty in applying that statement to the upper member is obvious, since it is not known that the complete original thickness has ever been measured; however, there is no reason to believe that its thickness varies inversely with the lower part of the formation in any place. The foregoing statements are confirmed by an isopach map of the middle sandstone member (Pl. 50), although the points of control for that map are fewer and less reliable than those for the entire formation, because the individual members are less easily distinguished in well records than is the entire formation from underlying and overlying formations.

LITHOLOGY

During the progress of field work done by the writer in the summers of 1932 and 1933, many exposures throughout the areas of outcrop were studied. Beds were measured and described in detail, and samples were collected from chosen beds. Where laboratory studies of the samples warranted alteration of the field descriptions, those changes were made, and all of the described sections were incorporated in an appendix [26] on file in the geology library at the University of Iowa. From the representative descriptions in the appendix, a general summary of the lithology of the Prairie du Chien sediments is made here.

ONEOTA DOLOMITE

A generalized description of the Oneota dolomite for any small area would have to be altered when applied to adjacent areas, because of gradual lithologic variations along the rather broad band

26 Powers, E. H. The Prairie du Chien Problems. Unpublished appendix, geology library, University of Iowa, Iowa City, Iowa, 1935.

of outcrops in northeastern Iowa, southeastern Minnesota, and western Wisconsin. Within the Minnesota River valley, the Oneota consists of massive beds (3 feet to 5 feet thick) of gray, pink and buff dolomite, which are quarried at Mankato and Kasota for building stone. Certain beds are of sufficient importance to have been given commercial names, which, however, do not extend beyond the quarries where they are applied. Quartz sand, silt, and shale are disseminated throughout the Oneota, at Mankato, though they rarely exceed 10 per cent of the rock by weight. At the base of the Oneota along Minnesota River, between Saint Peter and Mankato, fracturing and solution of the basal beds have allowed large blocks of dolomite to settle into beds of white shaly siltstone, which has been forced upward between them.[27]

The beds which occur at 10-20 feet above Minnesota River level at Shakopee contain a few nodular masses of gray, oolitic chert, and quartz sand locally predominates in thin beds and thin discontinuous lenses. The uppermost beds of Oneota on Minnesota River are exposed only at Mankato, where there is a sharp distinction from the overlying white New Richmond sandstone.

At Stillwater, Minnesota, massive beds of brownish Oneota dolomite rest on a slightly irregular surface of the Jordan sandstone. Of the 124 feet of dolomite exposed, there is no sandstone at or near the top that might be ascribed to the New Richmond. The writer agrees with Trowbridge and Atwater,[28] and with Clement,[29] that there is no evidence of an unconformity within the exposed beds, as Ulrich [30] had expressed, which might represent the contact of Oneota and "Shakopee."

Along the Saint Croix river in Washington County, Minnesota, and in Saint Croix and Pierce counties, Wisconsin, the Oneota consists of uniformly massive beds which are well exposed at Burkhardt (Pl. 51-a) and on Kinnikinick Creek. Quartz sand and small tabular dolomite pebbles are concentrated in certain beds within the section, but do not characterize any particular lithologic zone. Cryptozoon reefs, on the other hand, are abundant in some beds, as, for example, at 80 feet below the top of the Oneota at Willow

27 Graham, W. A. P. Petrology of the Cambrian-Ordovician contact in Minnesota. Jour. Geol. 41: 471-478. 1933; Stauffer, C. R., and G. A. Thiel. Jordan-Oneota contact along Minnesota River. Geol. Soc. Am. Preliminary list of titles and abstracts. 1933.

28 *Op. cit.*: 72.

29 Clement, G. M. Paleozoic stratigraphy and structure in the St. Croix River valley. Univ. Iowa Studies Nat. Hist. 16: 473-496. 1935.

30 Ulrich, E. O. Notes on new names in table of Paleozoic formations in Wisconsin. Trans. Wisconsin Acad. Sci. Arts and Letters 21: 100-108. 1924.

River Falls, Wisconsin. Local wavy structures occur in the upper beds of the Oneota on Willow River, Wisconsin, and are fairly common in Saint Croix and Pierce Counties, Wisconsin, and Dakota County, Minnesota. Some of the structures are reflected in the New Richmond sandstone and the upper dolomite member.

Within the broad band of outcrops along the Mississippi River from Hastings, Minnesota, to as far southeast as La Crosse, Wisconsin, the Oneota is characterized by uniform lithology and massive beds. For a distance of 50-75 miles certain beds of firm grayish brown dolomite with abundant cavities, 2 inches or less in diameter, occur within the lower 50 feet of the Oneota, in contrast to nonporous adjacent beds. Chert is a common but minor constituent of the dolomite in the outcrop northwest of La Crosse, Wisconsin, and Dresbach, Minnesota, whereas to the southeast it is abundant in certain beds. It occurs in nodular masses, either isolated or continuous along bedding planes of dolomite.

Several beds of distinctive lithology persist in Fillmore and Houston counties, Minnesota, in northeastern Iowa, and from La Crosse to as far southeast as Madison in southwestern Wisconsin. Alternating beds of sandstone and dolomite in the upper part of the Jordan sandstone cause difficulty in locating the plane of separation from the overlying Oneota. In the southern parts of La Crosse and Monroe counties, and throughout Vernon, Crawford, and Richland Counties, Wisconsin, there is in most sections a bed of conglomerate, 1-3 feet thick, at the base of the Oneota. It consists of a sandstone matrix with pebbles and boulders of sandstone, dolomite and chert, probably all derived within a very short distance from where they were deposited. The conglomerate is directly overlain, in most sections by 1-2 feet of very oolitic dolomite, which persists for 75 miles in Dane, Iowa, Richland, and Vernon Counties, Wisconsin. Within the outcrops of the Driftless Area in southwestern Wisconsin the persistent conglomerate and oolite beds are commonly overlain by glauconitic dolomite, 6 inches to 1 foot in thickness, which locally contains Cryptozoon reefs. Insoluble residues show a relatively high average per cent of quartz sand in the lower 5-10 feet of the Oneota. Sand predominates as lenses or thin beds in the lower 5 feet of some sections but may rarely be identified in more than one section. Glauconite produces a deep greenish color in the dolomite, and is of sufficient importance to be referred to in field descriptions as the "glauconite bed," immediately over-

lying the lowest "oolite bed." In exposures where there is a second bed of glauconitic dolomite, at 12-15 feet above the base, the two are distinguished as the "lower glauconite bed" and "upper glauconite bed." Within the lower 15-20 feet, Cryptozoon reefs characterize some beds locally but are not persistent. Where one of these beds contains Cryptozoon reefs replaced by chert, it is referred to as the "lower cherty Cryptozoon bed" and distinguished from the principal "cherty Cryptozoon bed." The more persistent bed occurs at 22 to 27 feet above the base of the Oneota and is recognizable at that horizon in practically every section within the Driftless Area in Wisconsin. Chert occurs in a thin discontinuous layer along the base of this bed and as vertically elongate and irregular masses replacing Cryptozoon reefs or dolomite between the reefs; and the chert content renders the bed conspicuous in exposures (Pl. 51-f).

Cryptozoon reef structures, ranging from 1 foot to 20 feet in horizontal dimension (Pl. 51-c and d), produce minor folds in associated beds of dolomite. They are particularly common in the upper Oneota and also the New Richmond and upper dolomite members at Nelson Dewey State Park, Wisconsin, where subdivision of the three members is difficult.

Beginning at about 45 feet above the base of the Oneota there is a 20 foot zone of brownish buff dolomite that is conspicuous in exposure by its relatively light shade of color, fine crystalline texture and regular bedding (6 inches to 1 foot in thickness). The insoluble residue consists principally of clay which is disseminated through the dolomite and concentrated as green shale laminae along bedding planes. This zone is recognizable in Houston County, Minnesota, in northeastern Iowa, and in La Cross, Monroe, Vernon, Crawford, Richland, and Sauk counties, Wisconsin.

No persistent lithologic character is restricted to any bed or zone within the upper 60-80 feet of the Oneota. Chert is a common constituent in the lower portion of this zone, as nodules and thin layers (Pl. 51-e). Large, irregular masses of chert are abundant in the "upper cherty beds" within the upper 40 feet of the Oneota in the Driftless Area, but do not occur in great abundance northwest of Trempealeau.

Exposures of the Prairie du Chien are rare in eastern Wisconsin to the northeast of Madison. A few exposures were studied and described for comparison with the lithology west of the northwest-southeast axis of the central Wisconsin arch. T. C. Chamberlin,[31]

31 Chamberlin, T. C. Geology of eastern Wisconsin. Geol. of Wis. 2: 268-285. 1877.

in 1877, described the Prairie du Chien beds of eastern Wisconsin. He was not able to recognize a three-fold division of the formation comparable to that west of Madison, possibly because the middle sandstone and upper dolomite units were removed by pre-Saint Peter erosion.

NEW RICHMOND SANDSTONE

The middle member of the Prairie du Chien in Minnesota River valley is a thin, but persistent bed of white friable sandstone. In the vicinity of New Richmond and Jewetts on Willow River, Wisconsin, its lenticular development involves some associated sandy beds, which are not certainly of New Richmond age, but may belong to the overlying dolomite member. At Point Douglas, Minnesota, there are 8-12 feet of conglomeratic sandstone overlying a slightly irregular surface of Oneota dolomite. Its content of cobbles and boulders of dolomite suggest wave agitation and shallower conditions of deposition than in the local basins to the east and west of this locality, which, incidentally, is near the axis of a minor anticline [32] and also the axis of an isopach low of the New Richmond sandstone (Pl. 50).

Exposures of New Richmond sandstone are rare in southwestern Wisconsin because of its slight thickness or because of its removal by post-Prairie du Chien and pre-Saint Peter or later erosion. At several places in La Crosse, Monroe, and Vernon counties, Wisconsin, the Saint Peter sandstone is known to rest on the New Richmond or in depressions in the Oneota. In southeastern Minnesota, as at Lanesboro, where the New Richmond is 44 feet thick, the member consists of massive white and slightly iron stained sandstone. At Preston, 4 miles southwest of Lanesboro, 4 feet of massive dolomite occur in the lower portion of the New Richmond. The occurrence of thin beds of shaly and cherty dolomite, interbedded with the sandstone, as at Lake City, Minnesota, and Lansing, Iowa, causes difficulty in distinguishing the New Richmond from the adjacent dolomite members. Beneath the surface, the New Richmond is identified by a predominance of sandstone, but beds of dolomite have been reported in it in Iowa [33] and both dolomite and chert in northern Illinois.[34]

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32 Trowbridge, A. C. Upper Mississippi Valley structure. Bull. Geol. Soc. Am. 45: 522-528, fig. 1. 1934.

33 Norton, W. H. Deep Wells of Iowa. Iowa Geol. Surv. 33: 104-437. 1928.

34 Needham, C. E. Contributions to the subsurface geology of northern Illinois, between the outcrops of the Saint Peter and Dresbach formations, with special reference to the

WILLOW RIVER (SHAKOPEE) DOLOMITE

The upper dolomite member of the Prairie du Chien at Burkhardt, Wisconsin, may be distinguished from the Oneota member by its thin bedded character (Pl. 51, compare a and b). Within the upper dolomite are several thin beds (2 inches to 1 foot and 6 inches) of sandstone and sandy dolomite which are distinct from the New Richmond sandstone at the base of the Willow River dolomite. There is a similar occurrence of thin sandstone beds within the Willow River at Cannon Falls, Minnesota. This member, as a whole, contains more sand than the Oneota dolomite. Shale and siltstone are important constituents in certain beds, as at Lanesboro and Preston, Minnesota, in northeastern Iowa, and at La Salle, Illinois. Chert occurs commonly in the Willow River, but nowhere in as great abundance as in the "upper cherty beds" of the Oneota (p. 432, this report). Oolites and glauconite are also present, but do not characterize any zone. There is some similarity, however, of the Cryptozoon reef structures to those of the Oneota. It may be generally stated that isolated exposures of Willow River dolomite may be distinguished, by field study, from Oneota dolomite.

SEDIMENTARY PETROLOGY

Approximately one thousand samples were collected from the Prairie du Chien sediments for laboratory investigation. Insoluble residues were prepared and petrographic studies were made. The writer plans to use the mineralogical analyses in a later report devoted to the sedimentary petrology of the formation.

Insoluble residues of samples from Minnesota River valley and from Lanesboro, Minnesota, have been studied by Tester and Couser.[35] Clement,[36] in 1933, studied insoluble residues from a few sections on Saint Croix River. The heavy accessory minerals below and above the Jordan-Oneota contact were studied by Graham,[37] in 1933, in sections on Minnesota River and on Mississippi River in southeastern Minnesota. Only such of these data as are necessary to substantiate the conclusions are included in the present paper.

New Richmond formation. Unpublished doctor's thesis. Northwestern University library. 1932.

35 Tester, A. C. and C. W. Couser. A petrographic study of the Prairie du Chien of the Minnesota River Valley, Minnesota. Unpublished manuscript. 1935.

36 *Op. cit.*

37 Graham, W. A. P. Petrology of the Cambrian-Ordovician contact in Minnesota. Jour. Geol. 41: 468-486. 1933.

Among the minerals of detrital origin are:

Garnet	Rutile
Zircon	Pistacite
Tourmaline	Titanite
Muscovite	Biotite
Common hornblende	Tremolite
Feldspars	Anatase
Magnetite or ilmenite	Quartz

Quartzite has also been introduced, but does not occur in abundance except where it has been derived from the quartzite formations in the Baraboo, Wisconsin, region. Abraded grains of chert have probably been derived both from distant sources and from reworking of chert deposited during the Prairie du Chien time. Tabular pebbles of dolomite occur commonly throughout the formation and are locally abundant in beds of conglomerate texture.

Among the minerals of secondary origin are:

Feldspars	Chert
Anatase	Chalcedony
Leucoxene	Pyrite
Quartz	Hematite
Galena	Limonite
Opal	

Calcite occurs as small veins and cavity fillings, and some dolomite is seen to be formed by recrystallization or direct precipitation, as within cavity fillings of residual clay. Siderite occurs in minute rhombs in the Oneota at Osceola, Wisconsin, and possibly in other sections. Both calcareous and siliceous oolites are common in dolomite and chert, with diameters of .75-1.5 mm. They either have no apparent nuclei or have grown around sand grains. A few siliceous monaxon and tetraxon sponge spicules have been observed from the Oneota.

Practically all of the minerals that have been described here have been found throughout the Prairie du Chien. An examination of the analyses of accessory minerals shows no great difference in their occurrences and relative abundance in the three members of the formation.

STRATIGRAPHIC RELATIONS

There is a gradual transition in lithology from the "Madison" beds of the Jordan sandstone throughout southwestern and southern Wisconsin, northeastern Iowa, and in the Mississippi valley region of

southeastern Minnesota. At Stillwater, Minnesota, on Saint Croix River, the beds of alternating sandstone and dolomite are not present, and Oneota dolomite rests on the slightly irregular surface of Jordan sandstone. At St. Peter, Kasota and Mankato, Minnesota, Oneota dolomite overlies a more or less lenticular development of white shaly siltstone. Graham,[38] in 1933, described this irregular contact as having been produced by post-Oneota solution above the top of the Jordan. Stauffer and Thiel,[39] later in the year, redescribed the contact and agreed with Graham's interpretation. Graham,[40] in 1933, found that the Jordan-Oneota contact, on Minnesota River, and in certain sections along Mississippi River in southeastern Minnesota, is not located at the same horizon in the field as where changes occur in analyses of heavy minerals. There are conglomeratic beds at the base of the Oneota in southwestern Minnesota, northeastern Iowa, and southwestern Wisconsin which might have been easily produced by subaqueous erosion. Twenhofel and Thwaites,[41] in 1919, suggested that the "quartzite-like" beds in the upper portion of the "Madison" may have been due to pre-Oneota case-hardening resulting from exposure before Oneota deposition. The writer believes, however, that there is conformity between the Jordan and Oneota in the upper Mississippi valley, except at Stillwater, Minnesota, and possibly on Minnesota River, where Graham[42] recognized a break in sedimentation by both field and microscopic evidence. In 1924, Ulrich[43] believed the entire Oneota to be absent at Jordan, Minnesota, and probably also at Ripon and Butte des Morts in eastern Wisconsin, but as stated by Trowbridge and Atwater[44] the entire Prairie du Chien has been removed at Jordan by post-Prairie du Chien erosion. The writer has found no physical or mineralogical evidence to support the belief that the entire 113 feet of Prairie du Chien at Ripon and the more than 100 feet at Butte des Morts are equivalent to the upper dolomite member of western Wisconsin. If Ulrich's[45] correlations

38 Graham, W. A. P. Petrology of the Cambrian-Ordovician contact in Minnesota. Jour. Geol. 41: 471-473. 1933.

39 Stauffer, C. R. and G. A. Thiel. Jordan-Oneota contact along the Minnesota River. Bull. Geol. Soc. Am. abstract. 1933.

40 Graham, W. A. P. Petrology of the Cambrian-Ordovician contact in Minnesota. Jour. Geol. 41: 486. 1933.

41 Twenhofel, W. H. and F. T. Thwaites. The Paleozoic section of the Tomah and Sparta quadrangles, Wisconsin. Jour. Geol. 27: 631. 1919.

42 Graham, W. A. P. *Op. cit.*

43 *Op. cit.*

44 *Op. cit.*: 69-70.

45 *Op. cit.* 83.

are correct, there would be a break at the Jordan-Oneota contact in western Wisconsin, represented by deposition of 2500 feet of "Lower Ozarkian dolomite" in Pennsylvania and Alabama, overlain stratigraphically by 2000 feet of "Middle Ozarkian dolomite" in the Appalachian region. The evidence for such a break in western Wisconsin would be entirely paleontological, because physical evidence is not only lacking in its favor, but rather indicates uninterrupted deposition, except for the production of brecciated and conglomeratic zones at the base of the Oneota, which occur within the Jordan and Oneota as well.

On the basis of meager faunas, Ulrich [46] placed the Oneota in the upper part of his proposed Ozarkian system and the "Shakopee" in the upper part of his Canadian system, thus recognizing a systematic break between the Oneota and "Shakopee" in the Upper Mississippi Valley, with the Lower and Middle Canadian missing between them. The New Richmond was considered as an introductory clastic phase of the "Shakopee." Where the New Richmond was thought to be absent, Ulrich cited physical evidences for location of the Oneota-"Shakopee" contact. At Stillwater, Minnesota, for example, the base of the "Shakopee" was placed at 60 feet above the base of the Oneota. His reasons for believing that the surface of the Oneota was eroded there before deposition of the "Shakopee" are as follows:

"(1) the relatively slight thickness of the lower formations, (2) the absence of the fossiliferous cherty zone, that is commonly present in the upper part of the Oneota at and to the south of Trempealeau, (3) the uneveness of the contact plane which shows irregularities of contour of a foot or more and corresponding dissection across sedimentary planes in distances of less than 10 feet, and (4) the presence of one to three inches of conglomerate with limestone and chert pebbles in a matrix of coarse quartz sand and grains of glauconite." [47] It was recognized that such a contact would be "affected and correspondingly obscured by secondary dolomitization." [48]

In criticism of the statements quoted from Ulrich above, the relatively slight thickness of the Oneota is thus assumed because he arbitrarily placed the top of the Oneota at only 60 feet above the top of the Jordan. The absence, at Stillwater, of the fossiliferous

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[46] *Op. cit.* 100-104.
[47] Ulrich, E. O. *Op. cit.* 101.
[48] Ulrich, E. O. *Op. cit.*

upper cherty zone that is present in the upper Oneota south of Trempealeau does not imply non-deposition or removal of those beds by pre-New Richmond erosion. Careful and extensive field studies show that the "upper cherty beds" of the Oneota (see p. 432 of this report), as well as other lithologic zones in southwestern Wisconsin gradually lose their identity northwest of La Crosse and Trempealeau. Bedding planes with an unevenness of even more than one foot in distances of 10 feet, described in the Stillwater section, can be duplicated in many sections of the Prairie du Chien at horizons of no stratigraphic importance. Beds of conglomerate, one to three inches in thickness, with pebbles of dolomite and chert in a matrix of dolomite and quartz sand have been found by the writer at many horizons throughout the Prairie du Chien less than 10 miles from Stillwater, at Burkhardt, Wisconsin, and in most sections within the area of outcrops.

Field study of a large number of sections, involving the three members of the Prairie du Chien, shows no physical evidence for a significant unconformity within the formation. Local disturbances within the New Richmond sandstone, lying on a slightly eroded surface of the Oneota, as at Point Douglas, Minnesota, might be accounted for by wave agitation in a shallow portion of the depositional basin. That suggestion is substantiated by the fact that the New Richmond sandstone is thin near the Hudson anticline and increases in thickness in the structural basins described by Trowbridge immediately east and west of the anticline (p. 428 of this report).

The quartz sand in insoluble residues of the Prairie du Chien at Burkhardt, Wisconsin, increases from the lower portion of the Oneota to a maximum in the New Richmond sandstone and decreases more or less gradually from the base of the upper dolomite member toward the top. Local folds there involve the upper Oneota, New Richmond, and the basal beds of the upper dolomite alike. Except for the section described at Point Douglas, Minnesota, no irregularities have been observed on the surface of the Oneota where it is overlain by the New Richmond sandstone. Many sections, as at Lake City and Preston, Minnesota, demonstrate a gradual transition from the upper Oneota into the lower New Richmond. The writer has found that the mineral suites of the three members of the Prairie du Chien are strikingly similar. This would indicate a close relation between them as members of a formation rather than substantiate a systemic break between the lower

and upper dolomite members. The writer, therefore, expresses the belief that there was continuous deposition throughout the Prairie du Chien in the Upper Mississippi Valley.

It is generally agreed that there is an erosional unconformity between the Prairie du Chien and Saint Peter formations. Trowbridge,[49] in 1917, described this unconformity in northeastern Iowa, and Trowbridge and Atwater,[50] in 1934, discussed it for the Upper Mississippi Valley. In many sections of southwestern Wisconsin, pre-Saint Peter erosion removed much or all of the upper dolomite of the Prairie du Chien, and in some places the Saint Peter sandstone rests on a very irregular surface of the Oneota. Subsurface data in southern Wisconsin and northern Illinois on thicknesses of the Prairie du Chien formation, when plotted on an isopach map (see Pl. 49), give a general concept of the amount of sediments removed from both the Prairie du Chien and from upper Cambrian sandstones before deposition of the Saint Peter sandstone.

CLASSIFICATION

PRAIRIE DU CHIEN FORMATION

The beds referred to the Prairie du Chien in this report are precisely the same as those to which the term was originally applied by Bain.[51] The geographic term was preferred to Owen's lithologic term, "Lower Magnesian" (see p. 422 of this report), as a regional term for the Upper Mississippi Valley. Where the entire thickness occurs, it was considered to include "(a) a dolomite at the base, 200 to 225 feet thick; (b) a sandstone in the middle, 15 to 130 feet, increasing to the southwest under cover; (c) a second dolomite at the top, approximately 40 feet in thickness."[52] In the bluff of the Mississippi River Valley, east of Prairie du Chien, Wisconsin, there is a complete exposure of the Prairie du Chien beds, consisting of 155 feet of dolomite below, overlain by 6 feet of sandstone and that in turn by 20 feet of dolomite. After an examination of representative sections of the Prairie Du Chien in the area of outcrops, a study of insoluble residues, a consideration of well records from geological reports and an examination of cuttings

49 Trowbridge, A. C. Prairie du Chien-Saint Peter unconformity in Iowa. Proc. Iowa Acad. Sci. 24: 177-182. 1917.

50 *Op. cit.*: 77-78.

51 Bain, H. F. Zinc and lead deposits of the Upper Mississippi Valley. U. S. Geol. Surv. Bull. 294: 17-19. 1906.

52 Bain, H. F. *Op. cit.*, p. 18.

from a few wells in Iowa,[53] the writer considers it advisable and practical to adopt Bain's original classification and to follow Trowbridge and Atwater [54] in classifying the term as a formation, consisting of three members.

This seems better than raising the Prairie du Chien to the rank of a group and the subdivisions correspondingly to formations. In such sections as at Stillwater and Hastings, Minnesota, stratigraphers disagree on the location of the Oneota-New Richmond and New Richmond-Willow River (Shakopee) contacts. Some even discount the New Richmond as a stratigraphic unit. Until the three units can be further subdivided by lithology and (or) fossils, the ranking adopted here should be retained. It is in harmony with the trend toward simplifying the classification of the lower Paleozoic sediments in the Upper Mississippi Valley.

ONEOTA DOLOMITE MEMBER

McGee's [55] term, Oneota, was generally accepted in and after the year 1892 for the lower dolomite unit of the sequence now known as Prairie du Chien. The writer adopts this well established term of McGee's for the beds of dolomite along the Upper Iowa River (old Oneota River), Iowa, and as the equivalent of Irving's Main Body of limestone, Wooster's Lower Magnesian proper, and Upham's Shakopee B limestone. In the Upper Mississippi Valley it is thus classified as the Oneota dolomite member overlying the Jordan member of the Trempealeau formation [56] and underlying the middle sandstone member of the Prairie du Chien formation.

NEW RICHMOND SANDSTONE MEMBER

Between the lower Oneota dolomite member and the upper dolomite member of the Prairie du Chien formation is a sandstone unit which is coextensive with them and which is not completely lacking in any place. Its thickness is 4 feet at Mankato, and 2-4 feet at Shakopee, Minnesota. Within the shoreward side of the outcrops in Wisconsin, it is 5-15 feet on Willow River and 5-10 feet in southwestern Wisconsin. In subsurface it is recognizable in most wells that have penetrated to the Oneota dolomite. There is, of course, difficulty in recognizing it in some wells where drilling records are

[53] Courtesy, Iowa State Planning Board, Project 1044-C, 1934.

[54] *Op. cit.* 21-30.

[55] McGee, W. J. Pleistocene History of northeastern Iowa. U. S. Geol. Surv. 11th Ann. Rept. pt. 1: 331-333. 1891.

[56] Twenhofel, W. H., G. O. Raasch, and F. T. Thwaites. Cambrian strata of Wisconsin. Bull. Geol. Soc. Am. Manuscript in press. 1934.

not adequate, and where its lithology does not allow a sharp distinction from the adjacent members. Where the sandstone is thin in Minnesota River valley and in Wisconsin, it might be easily penetrated in some wells without recognition. Quartz sand is an important constituent of the Prairie du Chien throughout, and within the dolomite members it locally predominates in certain beds as lenses, which the writer thinks, can in all cases be distinguished from the middle sandstone member. Wooster's choice of the type section of the New Richmond sandstone was unfortunate, because on Willow River it varies greatly in thickness within short distances, which is not typical of the unit throughout most of its extent in outcrops and in subsurface. Near the town of New Richmond, its lenticular development and poor exposure may cause it to be confused with the associated dolomite beds. Thwaites [57] was unable to distinguish the New Richmond sandstone from sandy beds of the Oneota in a deep well at New Richmond. At the upper Burkhardt dam on Willow River, however, the New Richmond sandstone unit is 5 feet thick and serves to delimit the upper part of the Oneota dolomite and the lower part of the upper dolomite member. In a discussion of the thickness of the Prairie du Chien (p. 428 of this report), attention was called to the coincidence of a minor syncline and an isopach high of both the New Richmond sandstone (Pl. 50) and the entire Prairie du Chien formation (Pl. 49) east of Burkhardt, Wisconsin. The suggestion of a local and more or less constricted basin of deposition in that area might account for the rapid increase in thickness of the New Richmond from 5 feet at Burkhardt to 10 feet between New Richmond and Jewetts and nearly 15 feet east of Jewetts on Willow River, the last of which occurs near the axis of the isopach high.

Perhaps it would be clearer to discard the poorly defined term, New Richmond, in favor of another geographic term chosen at a better exposure of the middle sandstone unit, as for examples, the sections at Lanesboro and Preston, Minnesota. Since the New Richmond was first applied, however, its stratigraphic position has been generally recognized, and the term has become well established in literature. It therefore seems advisable to follow the recent classification of Trowbridge and Atwater [58] and the suggestion of Wilmarth [59] in retaining the term New Richmond for the middle sandstone member of the Prairie du Chien formation.

57 Personal communication to the writer. 1933.
58 *Op. cit.*: 72-73, 79.
59 Wilmarth, Grace. Communication to the writer, Nov. 19, 1934.

WILLOW RIVER DOLOMITE MEMBER

The upper member of the Prairie du Chien formation has, since 1874, been called the Shakopee dolomite (Winchell, 1873) or the Willow River dolomite (Wooster, 1882). Outside of Minnesota River valley, the two terms have been used as exact synonyms. There has been a question as to whether the beds at the type section of the "Shakopee dolomite" belong to the lower or upper dolomite member of the Prairie du Chien. Because of incomplete exposure of any stratigraphic units and lack of lithologic individuality of the beds exposed at Shakopee, records of wells and plane table work must be relied upon to properly relate them to underlying and overlying beds.

Plane table work by Couser,[60] on Minnesota River, shows that the beds of the Shakopee type section occur in the structural and stratigraphic position of the Oneota. The question of whether there is slightly above and beneath Minnesota River level, at Shakopee, a thin sandstone underlain by a thick dolomite unit, equivalent to the New Richmond and Oneota, respectively, is clarified by an examination of cuttings from the artesian well within the city. A suite of cuttings was recently described and the stratigraphic section interpreted by the writer as follows:

Descriptive Log of the Water Works Well
Shakopee, Minnesota
October, 1934

Elevation of curb 725 feet.

	Thick (feet)	Depth Range (feet)
Ordovician system		
Prairie du Chien formation		
Oneota member:		
Dolomite; buff brownish, reddish brown in lower portion; sandy, 10% ±; cherty, gray, oolitic	54	0-54
Cambrian system		
Trempealeau formation		
Jordan member:		
Sandstone; color variable with layers, white, light gray, reddish brown and buff; texture, coarse grained beds interstratified with medium grained and fine to medium grained beds	112	54-168
St. Lawrence and Lodi members:		
Dolomite; light buff to grayish buff; fine to medium crystalline; sandy, locally, possibly contamination from Jordan; glauconitic, in lower 12		

60 *Op. cit.*

feet. Siltstone and shale; buff, grayish; in upper 5 feet; possibly Lodi		45	166-211
Franconia formation:			
Sandstone; greenish to grayish green, reddish green in lower 10 feet; glauconitic, finely disseminated and in large grains, responsible for green color of sediments; silty and shaly beds alternate with sandy beds		131	211-342
Dresbach formation			
Galesville member:			
Sandstone; pinkish gray in upper 50 feet, light to dark gray in lower portion; medium to coarse grained; friable		87	342-429
Eau Claire member		45	429-474
Siltstone; buff, grayish; firm; thinly laminated	14		
Shale; green, grayish; firm, in chips	11		
Sandstone; reddish; firmly cemented; fine grained; silty	12		
Sandstone; buff, pinkish; fine to medium grained; friable; major grade, ⅛-1/16 mm; principal subsidiary grade, ¼-⅛ mm	8		
Mt. Simon member		198	474-672
Sandstone; brown, reddish; medium to coarse grained; grains with ferruginous coatings; friable; major grade, 1-½ mm; principal subsidiary grade, ½-¼ mm	9		
Sandstone; brownish, light buff; medium to coarse grained; friable	5		
Sandstone; gray, light pinkish; medium to coarse grained; friable	34		
Sandstone; gray, light brownish; medium to coarse grained; friable	53		
Siltstone; gray, whitish; sandy, amount variable, 20% to 40%; drill cuttings powdered	38		
Sandstone; gray, slightly pinkish; medium grained; friable; well assorted	33		
Sandstone; gray, light buff; major grade, ½-¼ mm; principal subsidiary grade, 1-½ mm	26		
Cambrian (?)			
Red Clastic series (?)			
Hinckley sandstone (?)			
Sandstone; brown, reddish; major grade, 1-½ mm; principal subsidiary grade, ½-¼ mm; ferruginous coatings on grains; water from these beds gives problem of iron content; pressure raises water to 30 feet above level of curb		31	672-703
Total Depth		703	

A log of the J. A. Wilder well in the southeast part of Shakopee was published by Winchell [61] in 1888, and interpreted by Stauffer [62] in 1934, as follows:

LOG OF J. A. WILDER'S WELL AT SHAKOPEE

(River fill)	
Soil	2 feet
Yellowish stratified clay	5 feet
Sand and gravel, interstratified, coarsest below	38 feet
(Shakopee)	
Hard limestone	61 feet
(New Richmond)	
Quicksand and sandstone, plenty of water	2 feet
(Oneota?)	
Hard, cherty limestone	4 feet

That neither Winchell nor Stauffer knew the curb elevation of the J. A. Wilder well is demonstrated by their comparison of the "*New Richmond?*" (Stauffer) sandstone with a sandstone bed that was thought to occur, but not actually seen, at about river level in Shakopee.

The curb of the Wilder well is 905 feet above sea level. At an elevation of 860 feet, the top of the Prairie du Chien was entered. Below it, the drill penetrated 61 feet of dolomite and 2 feet of sandstone, which the writer ascribed to the upper dolomite and middle sandstone members, respectively, of the Prairie du Chien formation. Between the base of the sandstone at 797 feet in the Wilder well and the base of the dolomite at 671 feet in the City well, there is a thickness of 126 feet of beds ascribed by the writer to the Oneota dolomite member. A tabular summary of the Prairie du Chien formation at Shakopee is as follows:

	Thick (feet)	Elev. (feet)
Curb, J. A. Wilder well		905
Clay, sand and gravel	45	860
Willow River dolomite		
Dolomite	61	799
New Richmond sandstone		
Sandstone	2	797
Oneota dolomite		
Dolomite	4	793 (T.D.)
Unrecorded	61	732
Dolomite and sandstone, exposed	7	725

61 Winchell, N. H. Geology of Minnesota. Final Rept. 2: 125. 1888.

62 Stauffer, C. R. Type Paleozoic sections in the Minnesota Valley. Jour. Geol. 42: 350. 1934.

ERRATA

Since this paper was printed, Stauffer has learned that the original curb elevation of the city well at Shakopee was 12 feet below the present curb, or at an elevation of 713 rather than 725 feet; and also that the curb elevation of the J. A. Wilder well is 817 feet rather than 905 feet as printed in this paper.[1] The writer accepted this erroneous elevation for the Wilder curb from a determination made several years ago by engineers of the city of Shakopee, who placed the Wilder curb 180 feet above the present curb of the city well.

Considering these two corrections, the upper and lower parts of the general section at Shakopee work out from well data as follows:

J. A. Wilder Well	*Thickness*	*Elevation*
Clay, sand and gravel	45 feet	772-817
Dolomite	61 "	711-772
Sandstone	2 "	709-711
Dolomite	4 "	705-709 T.D.
Railroad cut and city well		
Dolomite	4 feet	728-732
Sandstone	2 "	726-728
Dolomite	1 "	725-726
Present curb city well 725.		
Dolomite excavated	12 "	713-725
Original curb city well 713.		
Dolomite	58 "	655-713
Jordan sandstone	112 "	543-655

The main difficulty now is in correlating the section in the Wilder well with that in the city well and the exposures near it. It is clear that the upper and lower parts of the section overlap. If the 2-foot sandstone of the Wilder well, at elevations of 709-711 feet, is identified with the 2-foot sandstone exposed in the railroad cut near the city well, elevation 726-728 feet, the general section might be interpreted as follows:

Willow River dolomite	61 feet
New Richmond sandstone	2 "
Oneota dolomite	71 "
Total Prairie du Chien	134 feet

[1] Personal communication from G. M. Schwartz to A. C. Trowbridge, dated October 28, 1935.

Or, if possible structure between the Wilder and city wells is ignored and both parts of the section stand without change, the general section might be as follows:

	Thickness	*Elevation*
Willow River		
dolomite	44 feet	728-772
New Richmond		
sandstone (exposed)	2 "	726-728
dolomite	15 "	711-726
sandstone (Wilder well)	2 "	709-711
Oneota		
dolomite	54 "	655-709
Total Prairie du Chien	117 feet	

Or, 54 feet or 71 feet of Oneota dolomite might be recognized, overlain by 63 feet or 46 feet respectively of Willow River dolomite, with two or more sandstone layers or lenses in its basal portion.

It might also be possible to recognize 117 feet (el. 655-772) of Oneota dolomite containing one or two thin layers or lenses of sandstone, the Willow River and New Richmond having been removed in the pre-St. Peter erosion interval.

According to recent studies by Schwartz[2], it does not seem possible to recognize the New Richmond by lithology and sequence in subsurface sections in the Twin City area. Perhaps the whole practice of distinguishing between Oneota and Willow River by position below or above the New Richmond should be discontinued for this particular area. In any case it is still not clear whether the beds exposed at Shakopee, that constitute the type section of the Shakopee dolomite, represent in their entirety post-New Richmond beds of other sections, or pre-New Richmond beds of other sections, or include New Richmond beds of other sections, together with some older and younger beds of dolomite.

2 G. M. Schwartz, personal communication to A. C. Trowbridge, dated Nov. 11, 1935

Curb, City Water Works Well		725
Dolomite	54	671
Jordan sandstone		
Sandstone	112	559

If, as Stauffer contends, the beds exposed at and below the quarries and at the site of the City well at Shakopee belong stratigraphically above the New Richmond sandstone and hence in the "Shakopee" formation or member, as the term Shakopee has been commonly used, the total section including the Wilder and City wells and the beds that lie between the bottom of the one and the curb of the other would be as follows:

Willow River dolomite and sandstone		173 feet
New Richmond sandstone		2 feet
Oneota dolomite		66 feet
Prairie du Chien formation	Total	241 feet

At no place in the whole area of outcrops is there a thickness of 173 feet of Willow River (Shakopee) dolomite. No thin sandstone showed up in the cuttings from the City well described by the writer (pp. 442) as Stauffer had described just above Minnesota River level. For comparison with the interpretation of the general section listed above, that of the writer may be summarized as follows:

Willow River dolomite		61 feet
New Richmond sandstone		2 feet
Oneota dolomite		126 feet
Prairie du Chien formation	Total	189 feet

In the light of the foregoing physical evidences, the writer concludes that the exposed dolomite beds of the Shakopee section belong in the lower 61 feet of the Oneota dolomite member. Wilmarth [63] suggested that, in the event that the type section of the Shakopee is proved to be of Oneota age, it would be advisable to "select the exposure of true Shakopee dolomite that is nearest to Shakopee and establish that exposure as the type section. . ." The nearest good exposure of the upper dolomite member in Minnesota is 36 miles southeast of Shakopee at Cannon Falls, and the nearest in Wisconsin is 45 miles from Shakopee near Burkhardt on Willow River. Of the two exposures, the one on Willow River is far better. At the Cannon Falls section it is difficult to describe the relation of the exposed beds to unexposed beds below and above, whereas, on

63 Correspondence to the writer, Dec. 8, 1934.

Willow River, the entire dolomite member and its contacts with the New Richmond sandstone below and the Saint Peter sandstone above are exposed. It would thus be confusing to describe the type section of the Willow River dolomite (Wooster) as the type section of the Shakopee. Trowbridge and Atwater,[64] in 1934, favored returning to Wooster's term Willow River if the Shakopee type section should be proved to belong to the Oneota dolomite. In spite of the firm establishment of the Shakopee in literature since 1874, it seems better to discard the term and to revive the term Willow River. That would not be as objectionable for replacement of Shakopee as a newly proposed name, since it was introduced only 8 years later (1882), and has not been entirely disused since that date. The term, Willow River, is therefore adopted for the upper dolomite member of the Prairie du Chien formation in the Upper Mississippi Valley with a detailed description of the exposure at the upper Burkhardt dam on Willow River for the type section, as follows:

Location: SW¼ sec. 2, T. 29 N., R. 19 W., below new dam on Willow River, 1 mile above Burkhardt, St. Croix County, Wisconsin.

The entire thickness of the Willow River dolomite is exposed between the top of the dam and the water level by the power house below the dam. The 5 feet of beds assigned to the New Richmond member were exposed at the dam in 1931 but are now below water level. However, they are exposed about 200 yards down stream and almost continuously to the lower Burkhardt dam.

Top. Elevation 913 feet.

	Ft.	In.
21. Sandstone; base of St. Peter		
Willow River dolomite		
20. Dolomite; buff, light brownish; medium to coarse crystalline; bedding, massive; conglomeratic, few scattered pebbles dolomite	1	3
19. Sandstone; brown, buff; medium grained; relatively firm; cement dolomitic, 20-40%; conglomeratic, small pebbles, 2% =; cross-bedded		6
18. Dolomite; buff, greenish; lithographic to medium grained; shaly, greenish, concentrated along bedding surfaces of thin beds; conglomeratic, pebbles of dolomite locally concentrated; sandy, lenticular, near top; bedding, thin to massive, 1-4 inches	2	
17. Dolomite; gray, buff to greenish; fine to medium crystalline, locally coarse; shaly, greenish, concentrated along bedding surfaces; sandy, 2-30%; conglomeratic, some beds with abundant granules and small pebbles of light buff dolomite; oolitic		

64 *Op. cit.*: 45, 72.

(calcareous), dissolved out of some beds to leave minute pores; gastropods, few, ½ inch in diameter	6	10
16. Sandstone; brown, buff; relatively firm; cement, dolomitic, content variable, 5-45%; medium grained; conglomeratic, few small pebbles of dolomite; thin bedded		1
15. Dolomite; buff; medium crystalline; relatively firm; minutely porous where calcareous oolites were dissolved; oolitic, abundantly; sand, 5-15%; bedding, thin, 2-4 inches	2	
14. Sandstone; grayish white to buff; fine to medium grained; shaly, greenish, disseminated and in thin seams; dolomitic, 20-35% of stratum, as cement and as thin dolomite beds alternating with sandstone; bedding, very thin, ¼ inch	2	
13. Dolomite; buff; firm; fine to medium crystalline, variable with beds; sandy, 0-20%; some beds minutely porous, may represent dissolved oolites (calcareous); conglomeratic, few small pebbles dolomite; gastropods, occasional, 5 mm. in diameter	4	4
12. Sandstone; gray, greenish; medium grained; shaly, greenish, thin seams; very thin bedded; interbedded with Dolomite; buff; fine to medium crystalline; lenticular; grades laterally into sandstone; beds involved in wavy structures with relief of 2 feet in horizontal distance of 20 feet	1	8
11. Dolomite; buff; medium to coarse crystalline; relatively firm; sandy, thin and discontinuous lenses; glauconitic; conglomeratic, some thin beds locally brecciated and with tabular pebbles of dolomite; zone with major wavy structure with relief of 5 feet in horizontal distance of 20 feet; gastropods, few, 10 mm in diameter	3	2
10. Dolomite; buff; medium to coarse crystalline; bedding, 6-10 inches; minutely porous; sandy, 0-10%; gastropods, 2-30 mm, abundant		11
9. Sandstone; gray; firm to friable; cement dolomitic; shaly, greenish; thin laminations; very thin bedded		2-4
8. Dolomite; buff, grayish; medium to coarse crystalline; relatively firm; minutely porous; sandy, 5-20%		6
7. Sandstone; white, greenish; fine to medium grained; thin bedded; shaly, greenish, disseminated and in thin seams; relatively firm, cement dolomitic; bedding wavy		6-9
6. Dolomite; gray; firm; medium crystalline; brecciated, possibly mud cracks and crevices later filled with dolomite; sandy, irregular concentrations, 6-10%		8
5. Dolomite; buff, grayish; firm; texture variable; very conglomeratic, granules, pebbles and cobbles of light buff dolomite, 20% =; sandy, medium grained, 20% =	1	5
4. Dolomite; buff, grayish; fine to medium crystalline; bedding, thin, wavy; conglomeratic, at top, 80% of bed; Sandstone; white to greenish; medium grained; shaly, greenish, thin seams and disseminated through sandstone; dolomitic; relatively firm; 20% of bed	1	

3. Dolomite; buff, grayish; fine to medium crystalline; sandy, 2-20%, variable with thin beds; shaly, greenish, locally concentrated on bedding surfaces; conglomeratic, thin beds with scattered pebbles of dolomite; bedding thin, slabby; gastropods, abundant on some bedding surfaces------------------ 4
2. Dolomite; buff, brownish to grayish; bedding irregular and thin; medium crystalline; sandy, 5-25%; conglomeratic, scattered pebbles of dolomite; gastropods, abundant on some beds----- 2

Total 36

New Richmond sandstone

1. Sandstone; massive; exposed in 1931, but now below water level 3

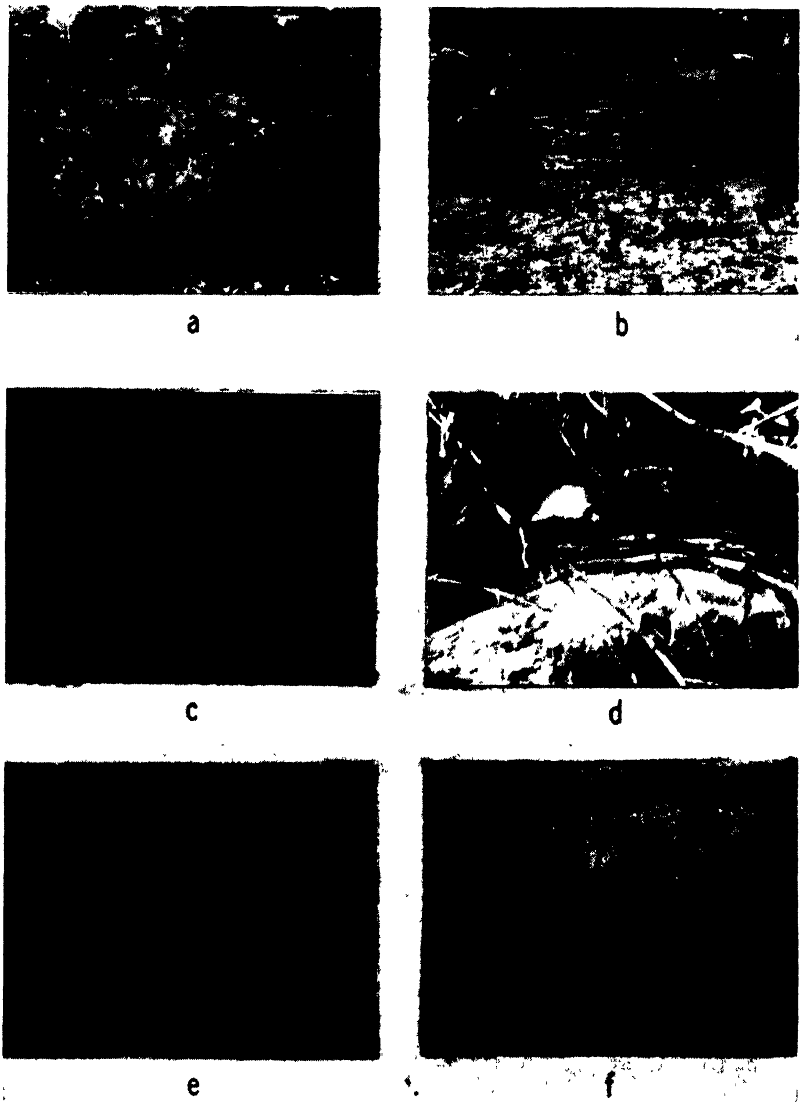

Plate 51

EXPLANATION OF PLATE 51

a. Massive beds of Oneota dolomite, Burkhardt, Wisconsin.
b. Upper 20 feet of Willow River dolomite, Burkhardt, Wisconsin.
c. Reef structure near top of Oneota, Preston, Minnesota.
d. Top of Cryptozoon reef in Oneota dolomite, Clayton, Iowa.
e. Nodules and thin layers of chert in middle Oneota, Chatfield, Minnesota.
f. "Cherty Cryptozoon bed" in lower 30 feet of Oneota, Madison, Wisconsin.

Paleozoic Stratigraphy and Structure in the Minnesota River Valley

by

CHESTER W. COUSER

Contents

INTRODUCTION

Type sections of the Saint Lawrence, Jordan, Shakopee, and Saint Peter formations or members occur on Minnesota River between its mouth at Fort Snelling and New Ulm. Other formations or members, mostly described before 1900, occur here also. Although the strata in this area have long been known not to be exactly horizontal, no detailed structural studies have been made previously. The purpose of this paper is to present the results of a restudy of these type sections and of other exposed sections in the Minnesota River valley and of structural plane table mapping of the same area and thus to contribute to the solution of the several stratigraphic and structural problems in the upper Mississippi Valley.[1]

Since this paper was completed and submitted for publication but before it was sent to the printer, a paper by Stauffer[2] has appeared, which in some sense is duplicated by the present investigation. However, as the conclusions and interpretations of the present writer in regard to a number of important stratigraphic points differ somewhat from those of Stauffer, and as all known sections, both surface and subsurface, whether type sections or not, and structure as well as stratigraphy are included, this paper is being sent to press without change, except for the insertion of this paragraph and some minor revision of phraseology, punctuation, etc.

STRATIGRAPHY

GENERAL STATEMENT

In this paper the formations are classified and named according to a scheme which has been tentatively agreed upon for the states of Wisconsin, Illinois and Iowa and which best expresses the writer's opinions concerning the divisions in the Minnesota valley. The classification used (Table I) is that tentatively proposed by

[1] Trowbridge, A. C. and G. I. Atwater. Stratigraphic problems in the upper Mississippi Valley. Bull. Geol. Soc. Am. 45: 21-80. 1934.

Trowbridge, A. C. Upper Mississippi Valley Structure. Bull. Geol. Soc. Am. 45: 519-528. 1934.

[2] Stauffer, C. R. Type Paleozoic sections in the Minnesota valley. Jour. Geol. 42: 337-357. 1934.

Trowbridge and Atwater[3] for the upper Mississippi Valley, as modified by Twenhofel, Raasch and Thwaites[4] for Wisconsin and by

Table I

Stratigraphic Section in the Minnesota River Valley[5]

System	Series	Formation	Member	Lithology	Thickness (feet)
	Mohawkian	Platteville		Limestone	30
Ordovician	Chazyan	St. Peter Unconformity		Sandstone	165
		Prairie du Chien	*Shakopee	Dolomite	150
			New Richmond	Sandstone	
			Oneota	Dolomite	
		local unconformity			
Cambrian	St. Croixan	Trempealeau	Jordan	Sandstone	110
			Lodi	Siltstone, sandstone, shale limestone	30
			St. Lawrence	Dolomite (?)	15
		local unconformity			
		Franconia		Sandstone, greensand, limestone, shale	145
		local unconformity			
			Galesville	Sandstone	70
			Eau Claire	Sandstone, shale	190
			Mt. Simon	Sandstone	115
		Unconformity (?)			
Cambrian?	Acadian (?) Waucobian (?) Keweenawan (?)	"Red Clastic"		Red sandstone, shale	50-1300
Algonkian	Huronian	Sioux		Quartzite	

* This is the Willow River (Shakopee) of Powers.

Trowbridge through Norton[6] for Iowa.

The Red Clastics and Dresbach formation and all of the Franconia but its uppermost beds are not exposed at the surface but are recorded in wells. All the exposures in the Minnesota River valley are located and numbered on figure 1.

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3 *Op. cit.*: 79.

4 Twenhofel, W. H., G. O. Raasch and F. T. Thwaites. Cambrian strata of Wisconsin. Bull. Geol. Soc. Am. In press.

5 Adapted from: Trowbridge and Atwater, *op. cit.*; Twenhofel, Raasch and Thwaites, *op. cit.*; and Norton, *op. cit.*

6 Norton, W. H. Deep wells drilled in Iowa, 1928-1932. Iowa Geol. Survey: 36. 1935. In press.

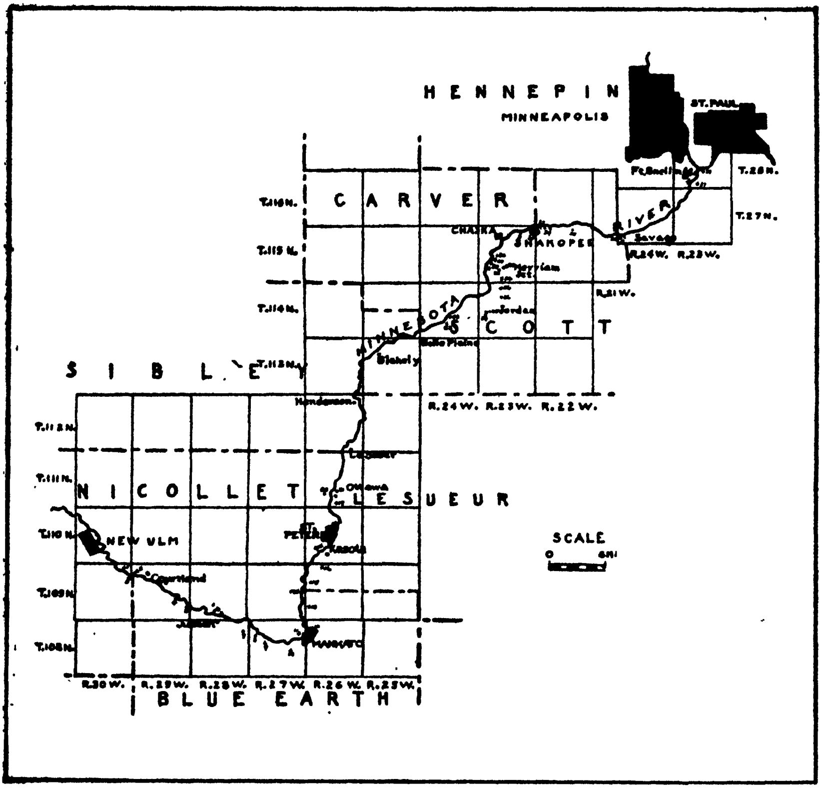

Fig. 1. Map of the Minnesota River valley from Fort Snelling to New Ulm. Numbers refer to exposures.

Exposure No.	Explanation
1	New Ulm quartzite. West-central Sec. 2, east-central Sec. 1, T. 109 N., R. 30 W.
2	Cretaceous shales. NE¼ Sec. 12, T. 109 N., R. 30 W., and NW¼ Sec. 7, T. 109 N., R. 29 W.
3	Cretaceous (?) sands. NE¼ Sec. 16, NW¼ Sec. 15, T. 109 N., R. 29 W.
4	Cretaceous (?) sands. SE¼ Sec. 23, T. 109 N., R. 29 W.
5	Franconia or St. Lawrence. SE¼ Sec. 25, T. 109 N., R. 29 W.
6	Franconia and St. Lawrence. East-central Sec. 33, SE¼ Sec. 28, SW¼ Sec. 34, T. 109 N., R. 28 W.
7	Jordan. NW¼ Sec. 12, T. 108 N., R. 28 W.
8	Jordan, South-central Sec. 7, T. 108 N., R. 27 W.
9	Jordan-Prairie du Chien contact. Central Sec. 17, T. 108 N., R. 27 W.

10	Jordan-Prairie du Chien contact. NW¼ Sec. 23, T. 108 N., R. 27 W.
11	Jordan-Prairie du Chien contact exposed for several miles along river road from Mankato toward Judson.
12	New Richmond in quarry NW¼ Sec. 7, T. 108 N., R. 26 W.
13	Fossiliferous upper Jordan, SW¼ Sec. 30, T. 109 N., R. 26 W.
14	Jordan-Prairie du Chien contact well exposed along river road from St. Peter to near Mankato.
15 and 16	Almost continuous exposures of Prairie du Chien in quarries.
17	Jordan-Prairie du Chien contact exposed on both sides of the river southwest of St. Peter.
18	Fossiliferous upper Jordan underneath new highway bridge NE¼ Sec. 21, T. 110 N., R. 26 W. (Exposure is now covered.)
19	Jordan-Prairie du Chien contact. White Rock quarry. SW¼ Sec. 34, T. 111 N., R. 26 W.
20	Jordan. Between Secs. 28 and 29, T. 111 N., R. 26 W.
21	Jordan-Prairie du Chien contact. Schwartz farm NW¼ Sec. 27, T. 111 N., R. 26 W. Other isolated exposures of Jordan and Prairie du Chien are found in the vicinity of Ottawa.
22	St. Lawrence. Type section. NE¼ Sec. 28, T. 114 N., R. 24 W.
23	Franconia-St. Lawrence contact. SE¼ Sec. 21, T. 114 N., R. 24 W.
24	St. Lawrence-Jordan contact in the bed of Sand Creek, below the breweries in Jordan.
25	Isolated exposures of Jordan at the type locality.
26	Isolated exposures of Jordan along Sand and Van Oser Creeks. Secs. 21, 28, 29 and 33, T. 115 N., R. 23 W., and Secs. 4 and 9, T. 114 N., R. 23 W.
27	Prairie du Chien. Upper St. Louis quarries, north-central Sec. 28, T. 115 N., R. 23 W.
28 and 29	Jordan-Prairie du Chien contact. East-central Sec. 20, SW¼ Sec. 21, and central Sec. 29, T. 115 N., R. 23 W.
30	Prairie du Chien. Lower St. Louis quarries, west-central Sec. 21, T. 115 N., R. 23 W.
31, 32, 33, 34, 35	Exposures in vicinity of Shakopee. (See text).
36	Prairie du Chien. Although not naturally exposed at the surface the Prairie du Chien is uncovered in many shallow excavations in the vicinity of Savage.
37, 38, 39	Platteville and St. Peter. Exposed on both sides of the river in the vicinity of Fort Snelling. Secs. 33, 32, 28, 21, T. 28 N., R. 23 W.

ALGONKIAN

Huronian

SIOUX

The Paleozoic rocks of the Minnesota River valley rest unconformably on a quartzite basement, the contact being somewhat

obscure. The easternmost exposure of the quartzite, which has long been correlated with the Sioux quartzite, is 3 miles west of Courtland, Nicollet County (1, fig. 1). The rock is thick-bedded and purple or reddish.

CAMBRIAN (?)

On the 1932 map of Minnesota no Paleozoic sediments appear in the Minnesota River valley east of a point midway between Judson and Courtland. West of this point the sediments are mapped as Cretaceous (2, 3, and 4, fig. 1). The Cretaceous rocks consist of red sandy shales and a few calcareous beds. Sandstones in this area have also been assigned to the Cretaceous.

The westernmost exposure of Cambrian rocks found by the writer occurs in the SE¼ of Sec. 25, T. 109 N., R. 29 W. (5, fig. 1). The strata exposed probably belong in the Franconia formation. Unless overlapped by younger Cambrian strata or buried beneath the Cretaceous sediments, the Red Clastics and Dresbach formation would be expected to appear at the surface between the westernmost Cambrian and the easternmost pre-Cambrian, a distance of about 7 miles. Within this area sedimentary rocks are exposed at a number of places of which some have been assigned previously to the Cambrian, some to the Cretaceous and some have been left in doubt.

Because of the stratigraphic position of these strata and the similarity of their heavy minerals to those of neighboring Cambrian beds, the writer believes that some of them may be of Cambrian age. However, the Cretaceous sea, advancing from the west over exposed Cambrian sediments may have reworked heavy minerals and reincorporated them within the Cretaceous deposits.

On the structure section (fig. 2) these beds of uncertain age are placed in the Cretaceous.

Red Clastic Series

With the possible exception of the exposures already mentioned, the Red Clastics are not exposed in the Minnesota River valley. They are recorded, however, in many wells. The total thickness in the Minnesota River valley is not known. The available data from wells are given in Table II.

Table II

Wells Showing Thicknesses of Red Clastic Sediments[7]

Location of Well	Thickness in Feet
Lake Crystal	50
Minneopa Falls	260+
Mankato	1300+
Henderson	200+
Minneapolis	1140+

In addition to the wells listed, wells at Jordan, Merriam Junction, Chaska and Shakopee are reported to have reached the Red Clastics. The Red Clastics are red shales, sands and sandy shales.

CAMBRIAN SYSTEM

Saint Croixan Series

DRESBACH FORMATION

The Dresbach formation in the upper Mississippi Valley consists of three members, a lower sandstone (Mount Simon), a shaly and sandy member (Eau Claire), and an upper sandstone (Galesville) (Table I). It is difficult to recognize the Red Clastic-Dresbach contact and the contacts between members of the Dresbach in drillings and the thicknesses assigned to the Dresbach formation and its members may vary considerably. Table III shows thicknesses of the Dresbach formation and its members at several places in the Minnesota River valley.

Table III

Wells Showing Thicknesses (in feet) of the Dresbach Formation and Its Members

Location of Well	Mt. Simon	Eau Claire	Galesville	Dresbach
Mankato	115	240	65	420
Merriam Junction	Mt. Simon & Eau Claire	272+	60	332+
Shakopee	98	173	95	366
South Minneapolis	130+	150	70	350+

The above data were obtained from the logs of the Shakopee well (p. 467), the Mankato well given by Upham,[8] and from the following well logs which have been interpreted by the writer.

[7] Hall, C. W., O. E. Meinzer and M. L. Fuller. Geology and underground waters of southern Minnesota. U. S. Geol. Survey, Water-Supply Paper 256: 141, 150, 200, 340, 341, 344. 1911.

[8] Upham, Warren. Geology of Blue Earth County, Minnesota. Geol. and Nat'l Hist. Survey. Final Report 1: 423. 1882.

Well log of C. St. P. M. and O. R. R., well at Merriam Junction water tank. Completed March, 1930. Elevation of well site—758 feet. Authority—Chief Engineer

	feet
Drift	
Clay and gravel	5
Limestone	3
Boulders and gravel	14
Clay and sand	17
Trempealeau:	
Jordan	
Soft sandstone	32
Hard sandstone	75
Lodi and St. Lawrence	
Gray shale	15
Limestone	24
Franconia:	
Green shale	145
Dresbach:	
Galesville	
Sandstone	60
Eau Claire and Mt. Simon	
Gray shale	10
Brown sticky shale	18
Green shale	22
Brown shale	30
Gray sandstone	15
White sandstone	120
Yellow sandstone	25
Pink sandstone	20
Red shale	12
	662

Well log of C. M. and St. P. R. R., well at South Minneapolis. Drilled April, 1917. Authority—Chief Engineer

	feet
Drift	
Sand and gravel	16
Hard pan and boulders	39
Platteville:	
Limestone	41
Shale and sandstone	8
St. Peter:	
Sandstone	106
Shale	15
Shale and sandstone	30
Prairie du Chien:	
Shakopee	
Hard rock	40
New Richmond	
Sandstone	5
Oneota	
Hard rock	70
Trempealeau:	
Jordan	
Soft sandstone	56
White shale and sand	24
Coarse sandstone	10
Lodi and St. Lawrence	
Shale and sand	40
Franconia:	
Shale	145
Dresbach:	
Galesville	
Sandstone	70
Eau Claire	
Shale	90
Sandstone	39
Shale and sandstone	21
Mt. Simon	
Sandstone	55
Red and yellow sand	35
Red sandstone	20
Yellow sandstone	10
Red Sandstone	5
Yellow sandstone	5
	995

Lithologically the formation in this area does not appear to be different from that elsewhere in Minnesota and in Wisconsin.

FRANCONIA FORMATION

Although Berkey,[9] in 1897, first named and described the Franconia formation as distinct from the Dresbach beneath and the Saint Lawrence above, it was not so recognized by Hall, Meinzer and Fuller [10] and has only recently been reassigned the rank of a separate formation in Minnesota.[11] In the present paper the Franconia includes beds consisting chiefly of sandstones and greensands that lie stratigraphically under the Saint Lawrence dolomite and over the Galesville sandstone. This is believed to be the original usage of Berkey and it is the present usage in Wisconsin and Iowa.[12]

In the Minnesota River valley the average thickness of the formation as defined above is about 145 feet. In the well at Ottawa, logged below and interpreted by the writer, the lower 131 feet are assigned to the Franconia. The base was not reached with the drill.

Well in Ottawa near river on Section line between Secs. 28 and 33, T. 111 N., R. 26 W. Well site elevation—747 feet

Well starts in Jordan which is exposed just north of the well site

	Feet
Trempealeau:	
Jordan	
Soft sandstone	40
Hard, white sandstone	20
Lodi and St. Lawrence	
Hard rock and shale	60
Franconia:	
Green shale, penetrated	131+
	251

The exposures of this formation in the Minnesota River valley are few. In the SE¼ of Sec. 21, T. 114 N., R. 24 W., Scott County (23, fig. 1) there are exposed about 5 feet of thin-bedded, brownish, glauconitic, sandy shale and dolomite, conglomeratic at the top, which is overlain by 5-7 feet of thick bedded Saint Lawrence dolomite. A short distance away in the NE¼ of Sec. 28, T. 114 N., R. 24 W. (22, fig. 1) is the type section of the Saint Lawrence where

9 Berkey, C. P. Geology of the St. Croix Dalles. Am. Geologist 20: 373. 1897.

10 *Op. cit.*: 47, pl. VI.

11 Stauffer, C. R. The Jordan sandstone. Jour. Geol. 33: 700. 1925.

12 Ulrich, E. O. Notes on new names in table of formations and on physical evidences of breaks between Paleozoic systems in Wisconsin. Wisconsin Acad. Sci., Arts and Letters 21: 77, 78. 1924.

Winchell[13] described 14½ feet of Saint Lawrence dolomite. This original Saint Lawrence section probably included the thin-bedded, glauconitic, shaly beds that underlie the dolomite in Sec. 21. Ulrich[14] considered these beds beneath the dolomite to represent the unnamed basal shale member of the Trempealeau formation. Such may be the case but they strongly resemble the uppermost beds of the Franconia elsewhere and have the same relations to the Saint Lawrence dolomite. In the opinion of the writer they belong in the Franconia and not in the Trempealeau. The Franconia-Trempealeau contact is between the Franconia and the Saint Lawrence dolomite and is placed at the base of the conglomeratic zone.

The Franconia is again exposed one-half mile north of Judson in Sec. 33, T. 109 N., R. 28 W., Nicollet County (6, fig. 1), where the Franconia-Saint Lawrence contact is exposed in the valley of the creek which enters the Minnesota River in the center of the section. The contact beds are similar lithologically to those described at Saint Lawrence.

TREMPEALEAU FORMATION

The Trempealeau formation consists of three members: the Saint Lawrence dolomite, the Lodi shale and the Jordan sandstone (Table I).

Saint Lawrence member. — The type section of the Saint Lawrence is at an abandoned town of that name 4 miles southwest of Jordan in Scott County. The quarry at Old Saint Lawrence (22, fig. 1), the type section, was described by Winchell.[15] A thickness of 14½ feet of beds was exposed at that time. The quarry is now partly filled with debris and the section exposed includes about 10 feet of thick-bedded, dark gray, glauconitic dolomite (Saint Lawrence) overlain by about 1 foot of thin-bedded, buff-colored dolomite (Lodi).

The only other exposures of the Saint Lawrence beds in the Minnesota River valley are in Nicollet County across Minnesota River from Judson, Blue Earth County, in Secs. 33, T. 109 N., R. 28 W., Sec. 28, T. 109 N., R. 28 W. (6, fig. 1). Most of these were described by Upham.[16]

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13 Winchell, N. H. Geology of the Minnesota Valley. Minn. Geol. & Nat'l. Hist. Survey, 2nd Ann. Rept.: 153. 1878.

14 *Op. cit.*: 88.

15 *Op. cit.*: 153.

16 Upham, Warren. Geology of Sibley and Nicollet Counties. Minn. Geol. and Nat'l. Hist. Survey, Final Report 2: 160-161. 1885; Geology of Blue Earth County. Minn. Geol. and Nat'l. Hist. Survey, Final Report. 1: 425-426. 1882.

Lodi member. — Between Saint Lawrence and Jordan, the Lodi member is concealed but in the bed of Sand Creek below the breweries in the town of Jordan the contact of the Lodi with the Jordan is exposed (24, fig. 1). This contact was mentioned by Winchell[17] in his report on the type section of the Jordan. Here the Lodi is sandy near the base of the Jordan member. The exact line of contact is difficult to determine because of the gradual lithologic change in the upper Lodi beds. The contact is placed where the composition of the rock seems about equally divided between sand and calcareous material.

The complete thickness of the Saint Lawrence and Lodi members in the type locality of the Saint Lawrence may be found from the difference in elevation of the Franconia-Saint Lawrence contact at Saint Lawrence and the Lodi-Jordan contact at Jordan, after correction for dip, if any. The difference in elevation is 26 feet. According to the best available data the beds in this locality strike in a direction N. 93° E. The line connecting the Franconia-Saint Lawrence contact at Saint Lawrence and the Lodi-Jordan contact at Jordan is almost an east-west line; therefore, the amount of dip between these points may be ignored. Therefore, the Saint Lawrence member appears to be about 10 feet thick and the Lodi member about 16 feet thick. However, 39 feet of Lodi and Saint Lawrence were penetrated in a well at Merriam Junction a few miles to the northeast (p. 459).

The only other exposures of these members are found near Judson, Blue Earth County, where a few feet of the Lodi are exposed above the Saint Lawrence dolomite.

Because it is difficult in well logs to determine the Saint Lawrence-Lodi and the Lodi-Jordan contacts it is not possible to give exact subsurface thicknesses to the Saint Lawrence and Lodi members in the Minnesota River valley. Wells which have penetrated the Trempealeau show thicknesses for the Lodi plus the Saint Lawrence of 40 feet at South Minneapolis, 39 feet at Merriam Junction, 60 feet at Ottawa and 40 feet at Mankato. On the 1932 map of the Minnesota Geological Survey a thickness of about 130 feet is assigned to the Saint Lawrence. The difference between this figure and the figures given above is probably to be accounted for by the fact that the Minnesota geologists include some of the Franconia (of this paper) in the Saint Lawrence.

[17] *Op. cit.*: 149.

Jordan member. — Alexander Winchell,[18] who named and described the type section at Jordan, Scott County, Minnesota, assigned a thickness of 51 feet to the formation in the type locality. Stauffer [19] repeated the original section in his later study. Hall and Sardeson [20] estimated that the formation is 35-40 feet thick at the type locality. The thickness of 51 feet for the type section was believed too great by N. H. Winchell [21] who thought that some of the beds in the type section were repeated. This the writer has found to be the case.

It was understood by Winchell when he defined the Jordan that only the lower beds are exposed at the type locality. The upper Jordan beds are exposed a few miles north of Jordan along Van Oser Creek. Plane-table work has shown that the uppermost bed of Jordan exposed at Jordan is at Foss's Mill, just east of the highway bridge, which is at an elevation 41.2 feet higher than the Lodi-Jordan contact in the bed of Sand Creek below the breweries.

The upper beds of the Jordan along Van Oser Creek four miles northeast (26, fig. 1) are about 25 feet thick, consist of sandstone, and are exposed below the Prairie du Chien dolomite. Between the beds at Jordan and the exposures on Van Oser Creek a considerable thickness of Jordan is concealed. After correction has been made for dip between these points it has been found that this concealed interval includes about 40 feet of Jordan.

Therefore, to study the complete type section of the Jordan two localities must be visited, i. e., the section at Jordan where the lower 41.2 feet of the member are exposed and the beds exposed along Van Oser Creek, about 25 feet thick. Between these two sections about 40 feet of beds are concealed. The thickness of the Jordan in the type locality is thus about 106 feet. The contact with the Prairie du Chien in this area is well exposed west of Merriam Junction (28 and 29, fig. 1). Here the upper 3 feet of the Jordan is dark brown to red, medium to coarse grained, thin-bedded, poorly cemented and is overlain by thick-bedded, dark gray to brown sandy dolomite of the Prairie du Chien.

Lithologically the Jordan is quite uniform. It is almost a pure quartz sandstone, mostly light colored but in places darker colored

18 Winchell, Alexander. Report of a geological survey in the vicinity of Belle Plaine. Senate Document, St. Paul, 1872.

19 *Op. cit.*: 705.

20 Hall, C. W. and F. W. Sardeson. Magnesian Series of the northwestern States. Bull. Geol. Soc. Am. 6: 176. 1895.

21 *Op. cit.*: 149.

because of iron. It is poorly cemented in the lower part and more tightly cemented in the upper part. The upper part is also somewhat coarser than the lower beds.

Wells which have penetrated the Jordan member show thicknesses of 90 feet at South Minneapolis and 107 feet at Merriam Junction. The average thickness of the member in the Minnesota River valley is probably about 100 feet.

In the area around Saint Peter and Kasota (13 and 18, fig. 1), sands that have previously been considered as upper Jordan contain gastropods which resemble those found in the Oneota. These fossiliferous beds have been mentioned by Stauffer [22] who believes them to represent reworking of the upper Jordan in Oneota time. Stauffer, and later Graham,[23] place the fossiliferous sands in the Oneota. Some silt which is white or bluish-white in color separates these sands and the Oneota dolomite at Ottawa, Saint Peter, Kasota and Mankato (14, 17 and 19, fig. 1). From about an inch in thickness on the Schwartz farm in the NE¼ of Sec. 27, T. 111 N., R. 26 W., at Ottawa (21, fig. 1), Le Sueur County, it thickens to the southwest and at Mankato (10 and 11, fig. 1) it is several feet thick. This silt may continue northward and explain the spring horizon a little above river level at Shakopee. At Saint Peter and Mankato this silt has been squeezed up into crevices of the Oneota due to solution and slumping of the dolomite.[24] Although formerly believed to be of Cretaceous age this clay is a part of the early Paleozoic section.

The contact of the Jordan with the Oneota on Minnesota River is one of slight unconformability. Graham,[25] Trowbridge and Atwater,[26] and Stauffer and Thiel [27] have discussed this unconformity.

ORDOVICIAN SYSTEM

PRAIRIE DU CHIEN FORMATION

The Prairie du Chien formation in the Minnesota River valley consists of three members, the Oneota dolomite, the New Richmond sandstone and the Shakopee dolomite (Table I). All this was included in the Shakopee formation of the early Minnesota reports.

22 *Op. cit.*: 706-707.

23 Graham, W. A. P. Petrology of the Cambrian-Ordovician contact in Minnesota. Jour. Geol. 41: 470-471. 1933.

24 Graham, W. A. P. *Op. cit.*: 471-472.

25 *Op. cit.*: 485-486.

26 *Op. cit.*: 76-77.

27 *Op. cit.*

Nearly all exposures of the formation have been described in the several county reports and only such new data as the writer has procured are presented. The distribution of the exposures of the formation is shown on Fig. 1.

Only three sections of the Prairie du Chien were studied in detail, i. e., at Mankato, at Merriam Junction and at Shakopee. The results of a textural and mineralogical study of the samples of these sections are presented in a separate paper.[28]

Mankato section. — Extensive quarrying is being carried on in the rocks of this formation at Kasota and Mankato and in the area between these towns (15 and 16, fig. 1). At these places the rock is thin to thick-bedded, brown dolomite.

The New Richmond is exposed along the road about midway between Mankato and Kasota and again in a quarry in the north-central part of Sec. 7, T. 108 N., R. 26 W., (12, fig. 1) in the northern part of Mankato. At this place about 60 feet of Oneota dolomite was measured above the Jordan contact. In the quarry the following section is exposed:

	Feet
3. Thin-bedded, dark gray to brown Shakopee (Willow River) dolomite..	2-3
2. White, friable, thin and cross-bedded, sandstone with occasional shaly partings, New Richmond	2-3
1. Thin to thick-bedded, dark gray to brown, Oneota dolomite. At the top is thin-bedded and contains *Cryptozoa*	30-40

Across from Sibley Park and at other places in and near Mankato (9, 10 and 11, fig. 1) the contact of the Jordan and Oneota is exposed.

Merriam Junction section. — At and near Merriam Junction 5 miles northeast of Jordan and 5 miles southwest of Shakopee there is a famous section of dolomite that has been interpreted differently by different workers. The lower 20-30 feet of the formation, consisting of thick-bedded, dark gray to reddish brown, sandy dolomite and a few shaly seams, is exposed in abandoned quarries on the east side of the river and forms the valley wall in the west-central part of Sec. 21, T. 115 N., R. 23 W. (30, fig. 1). Between these quarries and the upper Saint Louis quarries on the east side of the R. R. tracks in the north-central part of Sec. 28, T. 115 N., R. 23 W. (27, fig. 1), a few old shafts expose thin-bedded, light brown or buff colored dolomite which is wavy in places, and in

[28] Tester, A. C. and C. W. Couser. The Petrography of the Prairie du Chien of the Minnesota River valley. Manuscript in preparation.

places is interbedded with more massive layers. In some places the beds are cherty and shaly. These upper beds are oolitic at the top and farther east beyond the quarry contain large Cryptozoön masses. These peculiar fossils have been described by Winchell.[29] The top of the upper quarries is almost exactly 100 feet above the Jordan-Oneota contact in the base of the lower quarries. Winchell [30] believed the lower beds at Merriam Junction to be Oneota and the upper beds Shakopee which had been eroded back along the less resistant New Richmond. Stauffer and Thiel [31] have recently concluded that the strata are all of Oneota age with the exception of the upper few feet which are of Shakopee age.

The writer believes that all the dolomite beds exposed at Merriam Junction are equivalent in age to parts of the Oneota elsewhere. His reasons are: (1) the Oneota has a thickness of about 90 feet at Twin Cities [32] and probably attains an equal thickness at Merriam Junction although it does thin somewhat up the river, (2) no New Richmond is exposed and its presence between the lower and upper quarries as believed by Winchell is doubted, and (3) the structure is well known in this area and the New Richmond and Shakopee could hardly occur here, unless they replace the Oneota.

Shakopee section. — Almost all the published information on the rocks at Shakopee comes from a study of a single exposure, that in the quarry near the western boundary of the town. The writer found the rocks at Shakopee to be exposed at several places: (1) east along the south bank of the Minnesota River from Faribault Springs at the eastern boundary of the town, in the NE¼ of Sec. 6, T. 115 N., R. 22 W., and in the north-central part of Sec. 5 (34, fig. 1); (2) at the Schroeder quarry in the eastern part of Shakopee in the NW¼ of Sec. 6, T. 115 N., R. 22 W., (33, fig. 1); (3) along the R. R. tracks west of the city water works and east of the highway bridge; (4) along highway 5 in the west part of Shakopee (32, fig. 1), an exposure occurs also on Eagle Creek in the NE¼ of Sec. 3, T. 115 N., 23 W.; (6) in several excavations and cellars on the hill in the southern part of the town, and, (7) near the old brewery

29 Winchell, N. H. *Cryptozoon minnesotense*. Minn. Geol. and Nat'l. Hist. Survey, 14th Ann. Rept.: 313-315. 1886.

30 *Op. cit.*: 329; also, preface to vol. 2 of the Final Report, p. xvii. 1886.

31 Stauffer, C. R. and G. A. Thiel. The limestones and marls of Minnesota. Minn. Geol. Survey, Bulletin 23: 31. 1933.

32 Winchell, N. H. Geology of Ramsey County. Minn. Geol. and Nat'l. Hist. Survey, Final Report 2: 364. 1885. Sardeson, F. W. U. S. Geol. Survey Folio 201, Minneapolis-St. Paul: 5. 1916.

along the railroad tracks 1½ miles west of Shakopee (31, fig. 1). A small exposure occurs also on Eagle Creek in the NE¼ of Sec. 3, T. 115 N., R. 22 W., 4 miles east of Shakopee (35, fig. 1).

The maximum thickness of rock exposed at one place at Shakopee is in the Schroeder quarry. Here about 25 feet of rock are exposed. The rock consists of yellowish-brown, irregularly-bedded dolomite. The bedding is so wavy that some beds cannot be traced twenty feet horizontally. Sandy or shaly zones are common. A few beds of almost pure limestone are interbedded with the sandy dolomites. In places in the exposure east of Faribault Springs the beds are fossiliferous and oolitic and contain beds or more properly lenses of sandstone.

The best known exposure at Shakopee is in the west quarry. Sardeson [88] states: "fossils were found by me on the quarry dump, and also in the quarry wall under the main sandstone stratum." There are 21 feet of beds now exposed in the west quarry.

A log of a recently drilled well, located about midway between the two quarries, as interpreted by the writer, is given below.

Log of Well at City Water Works in Shakopee. Elevation of Well Site—725 feet

Rock	Thickness (feet)	Depth (feet)
Prairie du Chien		
Limestone	58	58
Trempealeau		
Jordan and Lodi		
Sandstone	146	204
St. Lawrence and		
Franconia		
Sandy limestone	133	337
Dresbach		
Galesville		
White sandstone	95	432
Eau Claire		
Sandstone and sandy limestone	173	605
Mt. Simon		
White and red sandstone	98	703
Very red at bottom — Red Clastics?		

This well shows the Jordan-Oneota contact at an elevation of 667 feet. Between the contact in the well and the lowest beds exposed in the east quarry only 38 feet of beds are not exposed. This is based on the beds being horizontal; however, it has been determined from

88 Sardeson, F. W. Type outcrops in Minnesota. Pan-Am. Geol. 41: 114. 1924.

plane table data that the strata in the area of Merriam Junction, Shakopee and Savage dip slightly northeast which would increase this figure to about 41 feet. This fact of the proximity of the beds at Shakopee to the top of the Jordan as shown in the city well led Trowbridge and Atwater [34] to express the view that the type section of the Shakopee might be of Oneota age.

This conclusion is favored by the writer. It seems clear that there are no beds equivalent to the New Richmond and Oneota beneath the dolomite exposed at Shakopee and above the Jordan sandstone that outcrops at Merriam Junction and is recorded in wells and test borings at Shakopee. According to the city well and other drillings which check it, not more than 38-41 feet of dolomitic beds are concealed above the Jordan sandstone (p. 467). By allowing for known dip it is computed that in the exposures east of Faribault Springs not more than 35 feet of dolomite can be concealed between the lowest exposed dolomite and the top of the Jordan sandstone. If there were anything like a normal thickness of New Richmond and Oneota beneath the beds exposed at Shakopee, there would have to be a syncline or other depression in the top of the Jordan, but surface and subsurface determinations prove that no such depression exists (fig. 2). It would be extraordinary if there were 90 feet of Oneota above the Jordan and beneath the Shakopee at Minneapolis 20 miles northeast of Shakopee and 90 feet of Oneota in the same position at Merriam Junction 5 miles southwest of Shakopee (p. 465) and no Oneota or at least less than 41 feet of Oneota in this position at Shakopee. As pointed out by Trowbridge and Atwater [35] this would mean that Winchell, who first used the term Shakopee for all of the dolomite and sandstone that directly overlie the Jordan and underlie the Saint Peter, was fortunate enough to have selected a place in which the dolomite correlates with a dolomite that overlies the New Richmond except in this one place.

Sardeson,[36] on the basis of the fossils he found, said the rock at Shakopee is of Shakopee age. Powell [37] when shown fossils collected from the exposure east of Faribault Springs, also believed the rock to be of Shakopee age.

[34] *Op. cit.*: 71.
[35] *Op. cit.*: 71.
[36] *Op. cit.*: 114.
[37] Powell, L. H. Personal communication to A. C. Trowbridge.

CHAZYAN SERIES

SAINT PETER FORMATION

The Saint Peter formation lies unconformably on the eroded surface of the Prairie du Chien. The name of the formation was given from the exposures at Fort Snelling (37, 28 and 39, fig. 1) at the mouth of the Minnesota River (earlier called the Saint Peter River), first described by Carver.[38] The formation was named and described by Shumard [39] in Owen's report of 1852.

The only other possible exposures of Saint Peter in the Minnesota River valley are [40] at the top of the Asylum quarry at Saint Peter, Minnesota, and in Rapidan township, Blue Earth County, along Maple River.[41] The rock at Saint Peter is now covered and Hall and Sardeson [42] later concluded that the rock on Maple River is Jordan.

The type section has been studied by Sardeson.[43]

The writer found the Saint Peter-Platteville contact underneath the north end of the Mendota Bridge to be at an elevation of 778 feet. Excavations for one of the piers of the Mendota Bridge struck the Prairie du Chien-Saint Peter contact at an elevation of 613 feet making a thickness of 165 feet for the Saint Peter in the type locality. Due to the erosional unconformity at its base, the thickness of the Saint Peter varies greatly within short distances.

MOHAWKIAN SERIES

PLATTEVILLE FORMATION

The Platteville formation lies conformably on the Saint Peter in the area near Fort Snelling. The contact is marked by the presence of several feet of bluish or greenish shale, the Glenwood, which is the basal member of the Platteville. The exposures in the vicinity of Minneapolis and St. Paul have been described by Sardeson.[44]

38 Carver, J. Travels through the interior part of North America in the years 1766, '67 and '68, p. 59. Dublin, 1779.

39 Shumard, B. F. Report of a geological survey of Wisconsin, Iowa and Minnesota by D. D. Owen, p. 481. 1852.

40 Winchell, N. H. The Geology of Carver and Scott Counties. Minn. Geol. and Nat'l. Hist. Survey, 2nd Ann. Report, p. 132. 1873.

41 *Idem.*: 133.

42 Hall, C. W. and F. W. Sardeson. Magnesian Series of the northwestern States. Bull. Geol. Soc. Am. 6: 176. 1895.

43 Sardeson, F. W. St. Peter sandstone. Minn. Acad. Sci. 4: 64-88, 1895; U. S. Geol. Survey, Folio 201, Minneapolis-St. Paul. 5-6. 1916.

44 *Op. cit.*: 6.

STRUCTURE

In the Minnesota River valley the strata dip toward a syncline which has been described by others.[45]

It is obvious that the rocks dip in a generally easterly direction from New Ulm where the pre-Cambrian rocks outcrop, to Minneapolis where pre-Cambrian rocks of equivalent age occur several thousand feet beneath the surface, and where the youngest rock at the surface is basal Galena dolomite. The regional dip cannot be determined accurately either in direction or amount. Several estimates made from the determination of the elevations of three points at the same stratigraphic horizon indicate that on the average the regional dip is about N. 71° E., in direction and about 16 feet per mile in amount.

The general easterly dip of the beds is complicated however by small and presumably local folds. Winchell [46] recognized an anticlinal axis in the vicinity of Belle Plaine and Hall [47] mentioned an arch in the pre-Paleozoic rocks in Rice, Goodhue and Dakota counties.

By determining the elevations of as many contacts as possible from exposures and wells the writer has prepared a section along Minnesota River from New Ulm to Fort Snelling (Fig. 2). As this section follows the river around the big bend at Mankato and all of its minor bends, the line of the section does not follow the line of true dip. It does not give a true picture of the structure, therefore, but does show the relations of the rock formations to the river.

No contacts were obtainable from either exposures of wells between Saint Lawrence and Ottawa and the structure in this part of the section is based on interpolation. Also, accurate data are not available between Judson and New Ulm, chiefly because the strata are obscured by Cretaceous sediments, and no claim is made to accuracy in this part of the section. The Red Clastics and Dresbach formation may be overlapped by younger beds or their outcrops may simply be covered by Cretaceous sediments.

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45 Hall, C. W., O. E. Meinzer and M. L. Fuller. Geology and underground waters of southern Minnesota. U. S. Geol. Survey, Water-Supply Paper 256: 32-33. 1911.

Trowbridge, A. C. and G. I. Atwater. Stratigraphy and structure of the upper Mississippi Valley. Abstract. Bull. Geol. Soc. Am. 42: 219-220. 1931.

Trowbridge, A. C. Upper Mississippi Valley structure. Bull. Geol. Soc. Am. 45: 519-522. 1934.

46 Winchell, N. H. Geology of the Minnesota Valley. Minn. Geol. and Nat'l. Hist. Survey, 2nd Ann. Rept.: p. 86. 1873.

47 Hall, C. W. Underground waters of eastern United States. U. S. Geol. Survey, Water-Supply Paper 114: 229. 1905.

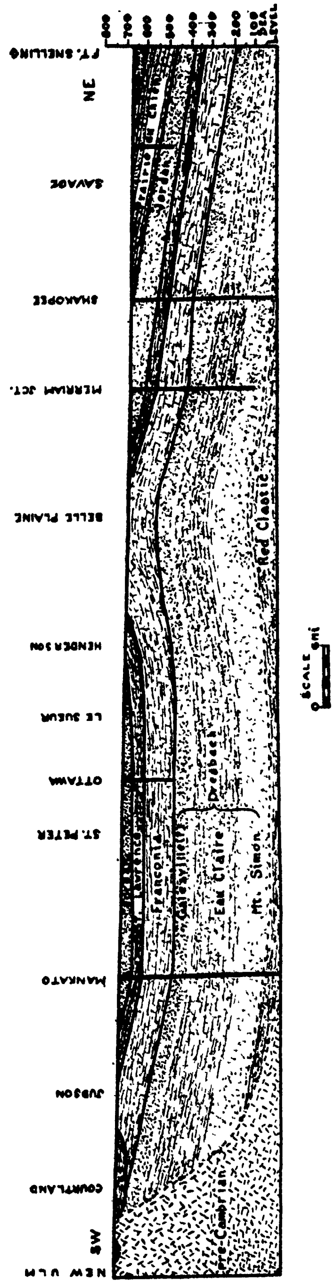

Fig. 2. Structure section along Minnesota River from New Ulm to Fort Snelling.

The synclinal axis that appears in the section crossing the river in the neighborhood of Saint Peter, due to the fact that the section is not straight, is apparent but not real. The facts are that the river flows down the dip and then in making the sharp turn at Mankato turns and flows nearly parallel with the strike of the strata. An anticlinal axis crosses the valley in the neighborhood of Belle Plaine. Because adequate control away from the river on either side is not obtainable, it is not possible to determine the strike or pitch of this fold.

CONCLUSIONS

The Red Clastics are present in the Minnesota River valley but this investigation does not contribute to the solution of the problem of age. The Dresbach formation in the Minnesota River valley is divisible with some uncertainty into three members, the Mount Simon, Eau Claire, and Galesville. The pre-Franconia strata near Judson are probably overlapped by Franconia and are covered by the Cretaceous. In the type locality of the Saint Lawrence this member appears to be about 10 feet thick and the Lodi member about 16 feet thick. In the type locality the Jordan is 106 feet thick but only the lower 41 feet are exposed at Jordan. The Jordan is separated from the Oneota on Minnesota River by a slight unconformity. The type section of the Shakopee is probably of Oneota age. The general eastward dip of the strata between New Ulm and Twin Cities is modified by an anticline at Belle Plaine.

Paleozoic Stratigraphy and Structure on Saint Croix River

By

George M. Clement

Contents

INTRODUCTION

Problems of stratigraphic classification, correlation, and nomenclature in the Upper Mississippi valley are apparent. Several classifications have been proposed and used, which differ one from another in important particulars. Recently another has been suggested tentatively by Trowbridge and Atwater [1] in the hope of clarifying some of these problems. This classification, after having been revised somewhat as indicated by Couser (p. 454 of this bulletin), harmonizes with the conclusions reached by the present writer and is adopted for use in this study.

The lower Saint Croix valley is the type locality of the Saint Croixan series and of the Franconia formation and contains several well known sections which have been differently interpreted by different stratigraphers. There are also structures in this area which have been known to exist but have not been studied in detail until now.

The purpose of this investigation was to make a new and detailed study of the rock formations and their structure in this classic area and, if possible, to solve the several problems involved, or at least to contribute to their solution.

The study involved detailed field work in which the plane-table and stadia alidade were used and the several formations were sampled, analytical work on these samples in the sedimentation laboratory, and library work in which the mass of literature bearing on this area was reviewed or abstracted.

The writer is indebted to Dr. A. C. Trowbridge for directing the field work and for making many suggestions in the preparation of the manuscript, and to Dr. A. C. Tester for assistance in the laboratory. Thanks are due also to Mr. Donald Laird and to Mr. John Mulroney who assisted the writer in the field, and to Mr. E. H. Powers, who described the valley of Willow River, adjacent.

STRATIGRAPHY

GENERAL STATEMENT

The general columnar section is shown on p. 454. Rocks that are exposed at the surface or are recorded in wells and are known to

1 Trowbridge, A. C. and G. I. Atwater. Stratigraphic problems in the Upper Mississippi valley. Bull. Geol. Soc. Am. 45: 21-80. 1934.

be of Upper Cambrian age lie unconformably on Keweenawan rocks which are probably mostly pre-Cambrian although the upper part may be Cambrian. Between the two is the Red Clastic Series which is probably equivalent to the upper part of the Keweenawan and which may be of Lower or Middle Cambrian age. Trowbridge and Atwater [2] have given a more nearly complete discussion of the relative ages of the Red Clastic and Keweenawan Series than is possible to give in this paper. More recently a separate paper on this same subject has been prepared by Atwater and Clement.[3] All the formations shown on the chart, except the Red Clastics and the Mount Simon, appear at the surface.

In this paper the rock formations are described and classified as they occur in this particular area. No attempt is made to solve the problems that may arise elsewhere.

The outcrops of the rocks of different ages are shown in figure 1.

MIDDLE CAMBRIAN (?)

Red Clastics

As indicated on the map (fig. 1), the Keweenawan rocks are exposed discontinuously from Conglomerate Point near Franconia, Minnesota, to Saint Croix Falls, Wisconsin, and beyond. South of Conglomerate Point the surface of the Keweenawan slopes off into a deep trough, the axis of which extends from the southwest tip of Lake Superior to southern Minnesota under Minneapolis and Saint Paul, and which contains the Red Clastic Series. The Red Clastic rocks, which are not known to outcrop, were penetrated in the Saint Croix valley by three wells.

Log of Stillwater Gas Well [4] NW¼ of SE¼ Sec. 28, T. 30 N., R. 20 W.

	Thickness	Depth
Elevation		783
Glacial drift	18	18
Oneota dolomite	85	103
St. Croixan sandstone	592	695
Red Clastic series, dark red, sandy, calcareous, shale, coarse quartz sand, fine calcareous sandstone and pink feldspar grains	2262	2957
Keweenawan trap	490	3447 T.D.

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2 *Op. cit.*: 26-31.

3 Atwater, G. I. and G. M. Clement Relation of the pre-Cambrian and the Cambrian in the Upper Mississippi valley. Manuscript so far unpublished.

4 Meads, A. D. The Stillwater deep well. Bull. Minn. Acad. Nat. Sci. 3: 274-277. 1891.

Log of Well of C. St. P. M. and O. Ry. at Shop Yard, Hudson, Wisconsin [5]

	Thickness	Depth
Elevation		670
Pleistocene		
Glacial drift	104	104
Dresbach		
Galesville sandstone	16	120
Eau Claire sandstone with shale	90	210
Mt. Simon sandstone	240	450 T.D.

Log of Well at Water Works South Hudson, Wisconsin [6]

	Thickness	Depth
Elevation		705
Pleistocene		
Glacial drift	50	50
Dresbach		
Galesville or Eau Claire		
Gray sandstone	50	100
Eau Claire		
Limestone	45	145
Mt. Simon		
Sandstone	247	392
Red Clastic Series		
Red shale and streaks hard rock	125	517
Red rock	40	557
Red shale and rock	365	922
Rock and shale	130	1052 T.D.

The Red Clastics as shown in the logs are 2262 feet thick in the Stillwater well, and at least 660 feet in the south Hudson well. The Railroad well at Hudson records the depth to the Red Clastic series, as the drilling stopped when that rock was reached.

Except for these wells, the Saint Croix area produces no evidence that can be used in determining the age or relationship of the Keweenawan trap and the Red Clastic Series. The Red Clastics, however, are younger than the main mass of Keweenawan trap.

CAMBRIAN SYSTEM

Saint Croixan Series

DRESBACH FORMATION

According to the classification used in this paper (p. 454), the Dresbach is the oldest formation of the Saint Croixan Series and

[5] Adapted from Weidman, Samuel and A. R. Schultz. The underground and surface water supplies of Wisconsin. Wis. Geol. Nat. Hist. Surv. Bull. 35: 550. 1915.

[6] Log supplied by McCarty Well Company to A. C. Trowbridge.

is divided into Mount Simon, Eau Claire and Galesville members. This formation is exposed in windows in glacial drift.

Mount Simon member. — The Mount Simon member does not outcrop in the immediate valley of the Saint Croix but is exposed on the Willow River about two miles from Hudson, Wisconsin, and is recorded in the deep wells at Hudson and at Stillwater. From these well records it appears to be about 245 feet thick. The outcrops on Willow River are not more than 40 feet below the base of the Eau Claire member. The rock is composed of friable, cross-bedded, well-sorted, medium-to-coarse grained, unfossiliferous sandstone and granular gravel, and some shale. The laboratory analyses are shown in Table I.

Eau Claire member. — The Eau Claire member is exposed (14, fig. 1) in the Willow River valley near Hudson, where the total thickness of the member is from 90 to 146 feet. Peterson [7] described the section near Little Falls Dam, four miles east of Hudson. This exposure shows the typical thin-bedded, friable, fine-grained, fossiliferous sandstone and interbedded shale.

Adjacent to the river channel one mile south of Taylors Falls five feet of white shale appear above the Keweenawan trap. (Section 1.)

Section 1 (2, fig. 1)

One Mile South of Taylors Falls, Minnesota

Lithology	Thickness in feet	Elevation
Pleistocene		
Glacial gravel	50	800-850
Franconia		
Upper member (unnamed)		
Sandstone, white, medium-to-thin-bedded, some glauconite; predominantly quartz and authigenic feldspars; trilobites abundant in lower beds, becoming less abundant near the top	19	781-800
Sandstone, thick, dark brown; white in fresh exposures; speckled with green and brown glauconite; few fossils.	45	736-781
Intermediate member (unnamed)'.		
Green, friable, glauconitic sandstone with interbedded shales and limestones near the top; top marked by numerous springs.	16	720-736
Concealed	19	701-720

[7] Peterson, Eunice. The Dreshbach formation of Minnesota. Buffalo Soc. Nat. Sci. 14: 33-34. 1929.

Dresbach formation		
Eau Claire member		
Shale, dark pyritiferous, with numerous fossils.	10	691-701
Shale, white-to-gray, fossiliferous. (This shale is nearly 50 feet thick in the St. Croix Falls tourist park	5	686-691
Level of St. Croix River		686

The Eau Claire member is very fossiliferous; the most numerous forms collected are *Linguella phaon*, *L.* (*Lingulepis*) *acuminata*, *Lingula pinnaformis*, *Anomocarella* sp., *Obolus polita*, *Hyolithes primordialis* and *Ptychoparia chippewaensis*. On the basis of these fossils this bed is correlated with the upper part of Peterson's Willow River section and with the rocks which outcrop in the Tostevin Quarry at Dresbach, Minnesota. Laboratory analyses of samples are shown in Table I.

In the field, the Eau Claire member can be differentiated from any other shaly member by the abundance and kind of its fossils. In the laboratory the member at Taylors' Falls is identified by (1) the difficulty in disaggregating the grains, (2) the gray silty nature of the particles, (3) the presence of 5 per cent or more of pyrite, (4) the absence of feldspars, and (5) the presence of fossil shell fragments.

Galesville member. — The Galesville (?) member is even less widely distributed along the Saint Croix than the Eau Claire although exposures occur in the city of Hudson and along the south side of Lake Mallalieu (16, fig. 1) as well as in Secs. 7, 8, and 12, T. 29 N., R. 19 W. (14, fig. 1). Although the Hudson section was described in detail by Wooster,[8] it is redescribed below, because some of the beds, especially in the upper part of the section, are better exposed now than they were in 1882.

Section 2

South Hudson, Wisconsin (17 fig. 1)

Lithology	Thickness in feet	Elevation
St. Lawrence		
Wide bench, probably made by the St. Lawrence member, although no rock was identified positively as St. Lawrence.	10.1	922.9-933.0
Franconia		
Upper greensand member		
Medium-to-fine quartz sand, with much glauconite,		

[8] Wooster, L. C. The geology of the Lower Saint Croix District. Geol. Wis. 4: 113, 114. 1882.

incoherent and shaly in places; concealed, except in a few places.	100.0	822.9-922.9
Intermediate member		
Limy beds, 2 to 6 inches thick, interbedded with greensand; few trilobites.	17.8	805.1-822.9
Greensands, fine-to-medium sandstone, with some green shale; glauconite very prominent.	35	770.1-805.1
Ironton member		
Buff calcareous sandstone; medium-grained quartz sand with some glauconite; numerous fragments of *Obelella polita*.	15	755.1-770.1
Dresbach formation		
Galesville member		
Brown medium-grained, friable quartz sandstone.	25.5	629.6-755.1
Concealed.	41.6	668.9-729.6
Level of St. Croix River.		668.0

On Willow River the member is 37 feet thick. Northward from Hudson, glacial drift and structural conditions conceal this member so that it is not exposed again except at Franconia, where only 5 feet of coarse sandstone separates the underlying trap from the Franconia formation.

Section 3

Franconia, Minnesota (3, fig. 1)

Lithology	Thickness in feet	Elevation
Pleistocene		
Glacial drift	77	823.0-900.0
Franconia		
Upper member		
Thick, white, fine sandstone; numerous trilobite remains; *Ptychoparia diademata* Hall and *Prosaukia misa* Hall are most abundant.	10.0	813.0-823.0
Sandstone, cross-bedded layers, very fine and thin; tobacco brown in color; numerous trilobites.	2.0	811.0-813.0
Sandstone, thick, white; very fine sand grains; a few calcareous brachiopod shells; a few trilobites; forms a cliff.	27.0	799.0-806.0
Middle member		
Sandstone, glauconitic; very fine grained; calcareous shaly beds near the top; forms a slope.	26.0	753.0-779.0
Ironton member		
Sandstone, white, coarse-to-medium, cross-bedded, with about 5 per cent to 10 per cent glauconite and numerous broken calcareous shells of *Obelella polita*.	20.0	733.0-753.0

Concealed.	6.0	727.0-733.0
Dresbach		
Galesville member		
Sandstone, quartzose; very hard, coarse-to-medium grained; cemented with iron oxide; samples show about 4 per cent leucoxene; unfossiliferous.	5.0	722.0-727.0
Concealed.	5.0	717.0-722.0
Keweenawan		
Diabase, dark in color	32.4	684.6-717.0
Level of St. Croix River		684.6

In the samples of the Galesville at Franconia, leucoxene makes up 70 to 80 per cent of the 1/8 to 1/32 millimeter grades, but only 4 per cent of the total sample. (Table 1). A few grains of unaltered ilmenite and a few grains of ilmenite showing alteration to leucoxene clearly indicate that the leucoxene was derived from the ilmenite *in situ*. As this mineral is very scarce in other horizons this zone may well be called the leucoxene zone.

Samples of the Galesville at Hudson differ widely from those at Franconia; at Hudson the Galesville more closely resembles the Franconia than the equivalent member at Franconia. Euhedral authigenic feldspars, in the finer grades, link this member at Hudson to the Franconia. Indeed the beds exposed at Hudson listed as Galesville may well belong in the Ironton.

In the field, the Galesville at Franconia can be determined from other sandstones by (1) stratigraphic position, (2) the silification and casehardening of the surface, and (3) the absence of glauconite and fossils. In the laboratory, the sizes and shapes of the grains alone do not differentiate this member from other sandstones, but it is recognized by (1) quartz grains having a secondary growth which are absent in the higher formations, (2) the presence of leucoxene in the Galesville and its absence elsewhere, and (3) the relative absence of authigenic feldspars which are found in the Franconia formation.

The Galesville at Hudson is tentatively differentiated from the overlying Franconia by (1) the absence of fossils, (2) the scarcity of glauconite, and (3) the contrast between the friable white sands of the Galesville and the brown oxide cement of the higher formation.

Undifferentiated Dresbach. — At Conglomerate Point, south of Franconia (5, fig. 1), 50 feet of conglomerate composed of angular boulders of diabase and basalt as large as 2 feet in diameter, cemented with fine silty material, is exposed above the Keweenawan

trap. Resting unconformably on this conglomerate is 5 feet of typical Ironton sandstone, which indicates that this angular material is probably Dresbach in age, but it may represent any or all of the members.

FRANCONIA FORMATION

Lying unconformably on the Dresbach, or on older rocks where the Dresbach is missing, is the Franconia formation (p. 454). This formation was named by Berkey [9] for the rocks which outcrop in the Saint Croix river valley near the village of Franconia, Minnesota. Berkey's original section is quoted as follows:

<table>
<tr><td rowspan="4">Basal Sandstone Series.

(Modified from Norton.)</td><td colspan="3">3. Franconia sandstone (100 feet).</td><td rowspan="3">The St. Croix Formation (Winchell.)</td></tr>
<tr><td rowspan="2">2. Dresbach shales (150 feet)</td><td>Obolella polita zone</td><td>Greensands and shales</td></tr>
<tr><td>Lingulepis pinnaformis zone</td><td>Calcareous and pyritiferous shales</td></tr>
<tr><td colspan="4">1. The lowest formation of this series is not exposed in the dalles area, but it includes the lowest sandstone beds and possibly also the "Hinckley sandstone," (0 to 1,000 feet).</td></tr>
</table>

Practically all geologists working in the Upper Mississippi valley now include in the Franconia the coarse arenaceous shaly greensands and coarse sands (*Obelella polita* zone). The formation in the type locality now includes three distinct members, as follows:

	Feet
3. Upper heavy beds of white-to-cream sandstone containing numerous impressions of trilobites	92
2. Intermediate beds of greensand interbedded with shale and a few thin calcareous beds near the top	26
1. Ironton member. Coarse-grained, cross-bedded, glauconitic sandstone. *Dicellomus politus* = *Obelella polita* zone	20
Total	138

Although the sands of No. 3 are not abundantly glauconitic in the type section at Franconia, their equivalents in practically all other sections in Wisconsin, Minnesota, and Iowa contain numerous beds and lenses of greensand.

Numerous sections of the Franconia, distributed along the Saint

9 Berkey, C. P. Geology of the Saint Croix Dalles. Am. Geol. 20: 373. 1897.

Croix from Afton, Minnesota, to Saint Croix Falls, Wisconsin, differ from one another and from the type section, but there is a general similarity both in character and in sequence of beds. Three miles north of the type locality, in the new road cut south of Taylors Falls (2, fig. 1), the upper part of the Franconia is well exposed. The greensand member, the top of which is here marked by springs, contains more and heavier limy beds and more shale than does the same member in the type section. In the river channel, the Ironton member of the Franconia is concealed by talus, but the fossiliferous Dresbach shales are exposed at the proper level. At Hudson, Wisconsin, (Section 2) approximately 35 miles south of the type locality, the same three members may be identified, although only the Ironton noticeably resembles the corresponding member of the type section. The intermediate member is much thicker (53 feet) and is composed of 35 feet of typical greensand and 18 feet of limy beds with a trilobite fauna near the top. The upper bed is approximately as thick as in the type section (100 feet), but differs in composition and in color. Whereas the type is white-to-cream, here the member is so heavily charged with glauconite that it is called the upper greensand. Sections between Afton and Taylors Falls show all transitions between the above two, yet each has its distinguishing characteristics. The thickness of the formation varies along the Saint Croix from 138 to 160 feet and increases toward the south.

The general mineral content of the Franconia is varied. In some places it is characterized by the presence of much glauconite which is responsible for the bright-to-dark-green color of the formation. Many of the sands are micaceous, especially in the vicinity of the type section. Above the southernmost trap on the Wisconsin side of the Saint Croix near Franconia, there are seams of intraformational conglomerate composed of pebbles of trap, some as large as 6 inches in diameter, interbedded with micaceous sandstone, but at the same level across the river in the type section there are coarse grits only. Laboratory analyses of sixteen samples taken are shown in Table I.

More than 30 per cent of the grains of the upper zone are authigenic feldspars which consist of euhedra of adularia, albite, microcline and oligoclase, listed in the order of abundance. The sizes of the grains vary from 1/2 to 1/256 millimeter; the majority are in the grades below 1/8 millimeter. In the grades 1/8 to 1/16 mil-

limeter and below, more than 50 per cent of the sample is composed of the authigenic feldspars. Only the grains in the larger sizes show signs of wear. Most of the euhedral grains have nucleii which in some cases extinguish at the same angle as the outer growth; in other grains the nucleii apparently are absent. The reasons for their absence in some grains may be (1) reabsorption by the new growth, (2) such orientation as to have the same extinction angle as the secondary growth, or (3) the absence of dust, which when present, outlines the nucleii. In occasional grains the twinning bands cross the secondary growth at the same angles as they do the nucleus. Muscovite is the mineral next most abundant, making up as high as 10 per cent of the sample, thus affording the sandstone a good cleavage.

In summary: The basal bed of the Franconia may be distinguished from the underlying Galesville at Franconia by (1) the frosted and pitted quartz grains in contrast with the grains showing secondary growth in the Galesville; (2) the high percentage of coarse grains of glauconite in the Franconia, and its absence below; (3) the absence of leucoxene in the Franconia; (4) the presence of numerous shell fragments in the basal bed, and their absence in the other sandstone. This last characteristic serves as an index to the member in many places. The intermediate bed may be differentiated from all other sandstone having a similar texture by its high glauconite and feldspar content. The upper member, like the intermediate bed, is remarkable for its fine sands and differs from all other similar sandstones by an extremely high percentage of authigenic feldspars. Just as high a percentage in the same sizes may be found in the residue of the Saint Lawrence and of the Prairie du Chien, but considering the whole sample the percentage is far below that of the Franconia.

TREMPEALEAU FORMATION

The third division of the Saint Croixian series, the Trempealeau formation, rests on the Franconia. In most places along the Saint Croix, this formation consists of three members: (1) a lower dolomite, the Saint Lawrence, (2) an intermediate yellow-to-green silty member, the Lodi, and (3) an upper sandstone member, the Jordan. The Trempealeau exposures are distributed irregularly along the Saint Croix from Afton, Minnesota, to a point two miles south of Franconia.

Saint Lawrence member. — In the greater part of the area, the

Saint Lawrence member, 10 to 15 feet in thickness, lends itself readily to mapping because of its greenish color and the distinct bench that it forms. From Marine to the "Soo" Draw Bridge the river flows parallel with the strike and this bench stands approximately 100 feet above the river level.

Lodi member. — This member lies directly on the Saint Lawrence dolomite member and can be distinguished in most places from it by its yellow calcareous siltstones and thin-bedded limestones in contrast with the heavier bedded dolomite beds of the Saint Lawrence (Section 4). But at Afton (Section 5) and at Osceola (Section 6) the Saint Lawrence and Lodi members are so similar as to prevent recognition separately. Analyses of samples taken every five feet fail to show any sharp line of demarcation; the beds having the stratigraphic position of the Lodi have as great calcareous content as the lower beds, although the grains of quartz are much smaller.

Section 4

One Mile South Osceola, Wisconsin

Lithology	Thickness in feet	Elevation
Trempealeau		
Jordan member		
White to yellow medium-grained cross-bedded sandstone	40	746-786
Lodi member		
Green siltstone with thin beds of dolomite, makes cascades in stream	17	729-746
St. Lawrence member		
Gray dolomite, some interbedded green siltstone, makes falls in stream	15	714-729
Franconia		
Upper member		
Fine white to cream, micaceous sandstone	26	688-714

Section 5

Afton, Minnesota (18, fig. 1)

Lithology	Thickness in feet	Elevation
Oneota		
Thick-bedded dolomite, bedding masked by secondary dolomitization	26	924-950
Trempealeau		
Jordan member		
Thick-bedded, yellow-to-white, coarse-to-medium sandstone; makes a cliff	121	803-924

St. Lawrence and Lodi members		
Green dolomitic silt with interbedded thin dolomite beds; some green shale; members not differentiated; fucoids and fragments of trilobites	31	772-803
Franconia		
Medium-to-fine sandstone with some interbedded shales near the top; heavily charged with glauconite	55	717-772
Concealed	41	676-717
Level of St. Croix River		676

Section 6

Osceola, Wisconsin (6, fig. 1)

Lithology	Thickness in feet	Elevation
Pleistocene		
Glacial drift	10.0	902.0-912.0
Prairie du Chien		
Oneota member		
Sandy dolomite; thick-bedded; reddish-to-purplish	4.0	898.0-902.0
Sandstone; brown; upper 2 inches green	3.0	895.0-898.0
Dolomite; in beds 2 to 3 feet thick; partings distinct; buff colored	26.0	869.0-895.0
— Unconformity —		
Trempealeau		
Jordan sandstone		
Sandstone; irregularly-bedded; medium-grained; brown	10.0	859.0-869.0
Sandstone; cross-bedded; white, with a few iron oxide stains	8.0	851.0-859.0
Sandstone; hard; medium-grained; with ferruginous cement	30.0	821.0-851.0
Concealed	24.0	797.0-821.0
St. Lawrence and Lodi members		
Siltstone; interbedded with thin calcareous beds; green; many fucoids; forms cascades; members not differentiated	45.0	752.0-797.0
Franconia		
Upper member		
Sandstone, medium-to-fine; white-to-greenish; some beds glauconitic	39.6	712.4-752.0
Concealed	30.0	682.4-712.4
Level of St. Croix River		682.4

It is unusual to find the Lodi exposed in its entire thickness because of the slumping of overlying materials or because of removal by erosion. In some places numerous springs mark the

position of the top. The combined resistance of the materials in the Lodi silts and the underlying dolomite in contrast to the friable sandstones of the underlying and overlying formations produce many falls and cascades.

The minerals of the two members are similar. The Saint Lawrence, where it is best developed between Marine and the "Soo" Draw Bridge, is coarser in texture and is more highly charged with glauconite than is the same member at Afton; otherwise the insoluble residue is much the same. In the Afton section, the material in the two members is very similar, consisting of more than 90 per cent of pitted and frosted quartz grains, mostly curvilinear, although the lower grades are angular. Glauconite is prominent in many of the samples, making up as much as 2 per cent of the size 1/4-1/8 millimeter, and as high as 30 per cent in sizes below 1/16 millimeter. The remainder consists of authigenic and detrital feldspars in sizes below 1/8 millimeter, and adularia, albite, microcline and oligoclase.

The mineral assemblages of the Saint Lawrence do not differ from the Prairie du Chien so greatly in species as in proportion. The Saint Lawrence can be differentiated from the Prairie du Chien by (1) solubility (an approximate average of 50 per cent, while the Prairie du Chien averages over 90 per cent), (2) the lower feldspar content (approximately 5 per cent of insoluble residues in contrast with the 50 per cent of the Prairie du Chien), (3) the high percentage of glauconite (5 per cent in contrast to the few grains in the Prairie du Chien). (See Table I.)

The more sandy and shaly zones of the Lodi can be differentiated from similar zones in the Dresbach and the Franconia by (1) the silty nature of the Lodi, (2) the high solubility and (3) the large feldspar content. Sizes of the grains alone differentiate the Saint Lawrence and Lodi insoluble residues from the Galesville member and from the Jordan and the Saint Peter formations.

Jordan Sandstone member.—The Jordan sandstone, the uppermost member in the Saint Croixan Series (p. 454), is exposed in the high bluffs from Afton, Minnesota, to Osceola, Wisconsin. The Saint Croix river flows almost parallel to the strike of the strata in the northern part of the area. A section, four miles southwest of Osceola, was described in detail by Stauffer [10] in 1925. The section at Stillwater, typical of the area, was described in 1888 by

10 Stauffer, C. R. The Jordan Sandstone. Jour. of Geol. 33: 710. 1925.

Winchell.[11] (Section 7.) The Jordan varies in thickness from 72 feet at Osceola to 121 feet at Afton, and has an average thickness of 75 feet. The formation is incoherent, although in many places the rock, due to casehardening of the surface, appears quartzitic. Unusual concretions of casehardened sandstone, 4 to 6 inches in diameter, were seen in the new road cut at Osceola. The lower beds, and some of the upper ones, contain flat sandstone pebbles, interbedded in a sandy matrix. The lithologic character of the sandstone is remarkably varied, but in the almost perpendicular bluffs along the river south of Osceola, three distinct units can be recognized.

(3) brown ferruginous sandstone containing many hard beds,
(2) pure white sandstone,
(1) cross-bedded sandstone, stained with iron.

The Jordan lies conformably on the Lodi, as indicated by the many cases of complete transition, and is overlain unconformably by the Prairie du Chien dolomite throughout the Saint Croix valley. The unconformity is recognized by (1) the presence of 1½ to 2 feet of basal sandstone conglomerate in the Oneota, (2) the complete absence of the transition beds exposed at Red Wing and at other places only a few miles southeast of the area, (3) the relative thinness of the formation compared with the Jordan farther south and (4) the truncation of the Jordan beds by those of the Prairie du Chien as seen in the new road cut at Osceola.

Laboratory analyses of eleven samples taken from the Jordan are shown in Table I. The Jordan can be differentiated from the Galesville by (1) the pitted and frosted character of the grains in contrast to the secondarily grown grains of the Galesville, (2) the absence of leucoxene in the Jordan and its presence in the Galesville and (3) the relatively high percentage of zircon in the Jordan. It can be distinguished from the Franconia by its larger grains, and from the Saint Peter by the high degree of roundness and the mineralogical purity of the Saint Peter.

ORDOVICIAN SYSTEM

Prairie du Chien Formation

The Prairie du Chien formation is divided into the Oneota, the New Richmond and the Shakopee members. This formation outcrops along the Saint Croix river from the mouth at Prescott to

11 Winchell, N. H. Geology of Washington County. Geol. of Minn. Final Rept. 2: 387. 1888.

Osceola, Wisconsin. Exposures are not continuous because of removal by erosion or cover by drift, but wherever exposed the rock forms conspicuous cliffs or bluffs along the river and cuesta ridges away from the river. The bluffs are 185-200 feet high. The entire thickness of the formation is present only in the southern part of the area.

The Oneota member is chiefly thick-bedded, tough, crystalline, dolomitic limestone, with a few lenses of sandstone, varying in color from grayish or dirty buff to light buff or drab. In artificial exposures the beds are thick and fairly regular and have distinct partings, but in natural exposures the bedding planes are lost through secondary dolomitization. Many of the beds contain numerous solution pores. For no great distance are any of the beds mapable units.

The Stillwater section (Section 7) is typical of the exposures in the southern part of the area and the Osceola section (Section 6) of those in the northern part.

Section 7

Stillwater, Minnesota (11, fig. 1)

Lithology	Thickness in feet	Elevation
Pleistocene		
Glacial drift	70	915-985

ERRATA

After this paper went to press, Stauffer discovered a fauna at Stillwater in dolomite 100 to 105 feet above the Jordan.[1] This is identified as a Shakopee fauna. Either the present writer is wrong in assigning all of the dolomite above the Jordan to the Oneota as usually defined, or the Shakopee fossils occur in this section stratigraphically below the New Richmond horizon.

1 Personal communication from G. M. Schwartz to A. C. Trowbridge, dated January 8, 1936.

Thin-bedded calcareous shales and siltstones with many springs at the top	13	668-681
Level of St. Croix River		668.0

The New Richmond member is represented on Willow River about 5 miles from Hudson by two beds of sandstone 2 or 3 feet thick and lying about 120 to 130 feet above the base of the Oneota.

This outcrop is only about 6½ miles from the type locality. No sandstone was found in the upper part of the 126 feet of Prairie du Chien at Stillwater, which might be ascribed to the New Richmond.

Most of the fossils that are found in the Prairie du Chien are very poorly preserved. Cryptozoons are common; gastropods of the genus *Ophilita* also are abundant, and *Hexactinellidae* sponge spicules were found in beds 33, 50, and 70 feet above the base of the Oneota at Stillwater.

The mineral assemblage in the different parts of the Prairie du Chien formation varies considerably in species, shape and size. Samples were taken at regular intervals of five feet in the Osceola and Stillwater sections, but in all the other localities the unusual beds only were sampled. In some of them chert occurs in the form of geodes, layers and oolites. Laboratory analyses of samples are shown in Table I.

The minerals in the Stillwater section are noticeably different from those at Osceola. The most soluble bed in the section is 60 feet above the base of the formation. The dolomite has a soluble carbonate content varying from 80.2 to 99.12 per cent, and an average of 91.2 per cent. Some of the insoluble grains are as large as 1/2 millimeter in diameter, although most of them are less than 1/16 millimeter. The dominant mineral is authigenic feldspars, consisting of euhedral grains of adularia, albite, oligoclase and microcline, which compose 30 per cent to 60 per cent of the insoluble residue. The grains of feldspar range from 1/32 to below 1/256 millimeter in diameter. Curvilinear shaped quartz grains are next most numerous, and very fine clay makes up an appreciable part of some of the residues.

Studies of mineral suites from the Prairie du Chien of the Stillwater section do not indicate a stratigraphic break in the upper part or at 60 feet above the base as believed by Ulrich, but rather support the classification of all of the exposed beds as Oneota.

In 1924, Ulrich[12] proposed to place a systematic break within this dolomite by classifying the Oneota in his Upper Ozarkian and the Shakopee in his Upper Canadian. He believes the New Richmond to be a lens or a series of lenses at different horizons rather than a member or formation. Part of Ulrich's physical evidence for this proposed division lies in the Saint Croix area.

12 Ulrich, E. O. Notes on the new names in table of formations and on physical evidence of breaks between Paleozoic systems in Wisconsin. Trans. Wis. Acad. Sci. 21: 100-104. 1924.

His evidence for a physical break 60 feet above the top of the Jordan between the Oneota and the Shakopee at Stillwater is: "The relatively slight thickness of the lower formation [the Oneota], (2) the absence of a fossiliferous cherty zone that is commonly present in the upper part of the Oneota sections at and to the south of Trempealeau, (3) the unevenness of the contact plane which shows irregularities of contour of a foot or more and corresponding dissection across sedimentary planes in distances of less than ten feet, and (4) the presence of one to three inches of conglomerate with limestone and cherty pebbles in a matrix of coarse quartz sand and grains of glauconite." [13]

In addition to taking samples every five feet for laboratory analyses, the writer carefully examined the Stillwater section to determine the possibility of a physical break within the Prairie du Chien formation. The writer found no more evidence in the field for placing the contact between the Oneota and the Shakopee 60 feet above the Jordan than at any other level. That is, the Oneota has about the same thickness at Stillwater as on Willow River and almost as great a thickness as at Dresbach, Prairie du Chien, and elsewhere on the Mississippi River. The lenticular character of the cherty zones in the Prairie du Chien renders the presence or the absence of such zones of doubtful value for purposes of classification in the Saint Croix area. The unevenness of the bedding at the 60-foot level is duplicated at many different horizons in the Prairie du Chien. Many such irregularities of contour — due to truncation of cryptozoan reefs and diastems — indicating even greater breaks than the one at Stillwater can be observed along the railroad cut west of Point Douglas, at Hastings and elsewhere, in different stratigraphic positions. If such evidence were to be so used, there would be scores of great unconformities in the Prairie du Chien. If there is a break between two systems at the 60-foot level, it will have to be determined on paleontological evidence, for physical evidence seems to the writer to indicate the contrary.

Saint Peter Sandstone

South of Stillwater, the Saint Peter sandstone directly underlies the steep slopes of erosion remnants that are capped by Platteville limestone. These flat-topped hills stand approximately 100 feet above the surrounding country. Following is a typical section:

[13] *Op. cit.*: 101.

Section 8

North of Prescott, Wisconsin, in Secs. 25, 26, and 36, T. 27 N., R. 19 W. (20, fig. 1)

Lithology	Thickness in feet	Elevation
Pleistocene		
Glacial drift	15	1045-1060
Platteville limestone		
Thick-bedded, broken, buff-colored, fossiliferous, dolomitic limestone	7.5	1037.5-1045.0
Fossiliferous dolomitic limestone	5.5	1032.0-1037.5
Glenwood shale member; green shale	4.0	1028.0-1032.0
St. Peter		
Thick-bedded, ferruginous sandstone	2.0	1026.0-1028.0
Loose, friable, white sandstone	8.0	1018.0-1026.0
White sandstone; makes a distinct bench	5.0	1013.0-1018.0
Friable sandstone; mostly concealed	120.0	893.0-1013.0
Prairie du Chien		
Bedded dolomite, with coarse quartz sand	2.0	891-893
Bedded dolomite; only partly exposed; lowest rock seen near river level is close to contact with the Jordan	185.0	796-891

The basal portion of the formation is concealed in most places, making difficult an actual measurement of the thickness, but from several measurements in the field and from well records, the Saint Peter south of Hudson is known to be 130 to 133 feet thick.

Trowbridge,[14] describing an unconformity beneath the Saint Peter in Iowa, found that the thicknesses of the Prairie du Chien and Saint Peter formations vary reciprocally, but sum up to about 300 feet, and stated that the buried erosional surface under the Saint Peter has a relief as great as any similar surface in the Paleozoic in the Mississippi valley. However, on Willow River only a few miles from the Saint Croix, Powers[15] traced this same contact for 1½ miles and found a relief of only 4 feet. So far as can be determined the thicknesses of the two formations do not vary greatly from place to place in the Saint Croix river region, and their combined thicknesses amount to as much as 322 feet. It is possible that there is no important unconformity between the Prairie du Chien and the Saint Peter formations in this particular area.

14 Trowbridge, A. C. Prairie du Chien-Saint Peter unconformity in Iowa. Proc. Iowa Acad. Sci. 24: 177-182. 1917.

15 Powers, E. H. Paleozoic stratigraphy and structure in the valleys of Willow and Apple Rivers, Wisconsin. Unpublished thesis, Univ. of Iowa. 1932.

Much of the Saint Peter sandstone is somewhat cross-bedded, and near the top there are several hard layers cemented with iron. Many of the weathered faces are yellowish-to-reddish, but the fresh exposures are white, excepting the few ferruginous beds near the top.

The formation consists of bedded, white, friable, saccharoidal, quartzose sandstone. Most of the grains are frosted, highly polished and curvilinear, but some are sub-rounded. Mechanical analyses are shown in Table I. The few heavy minerals which were seen under the petrographic microscope were not separated from the light minerals.[16]

Platteville Formation

In the Saint Croix area the Platteville limestone occurs only on the tops of erosional remnants south of Stillwater. Only 10-17 feet of the lower part of the limestone and 2-4 feet of the basal Glenwood shale member are known anywhere within this region (Section 8), the younger beds of the formation having been eroded from the tops of the hills.

The green Glenwood shale probably represents transition from the Saint Peter sandstone to the Platteville, which in this region consists of blue-to-gray, fossiliferous, thin-bedded dolomitic limestone.

Decorah Shale

If there were any rocks younger than the Platteville deposited in this area, they have been removed by erosion, except for traces of the Decorah shale. No exposures of this shale have been found in place along the Saint Croix, but in the faulted area near the "Soo" Draw Bridge, Peterson[17] reports "float" made up of slabs of Decorah.

STRUCTURE

As has long been known, the Paleozoic strata in this general region dip gently from the pre-Cambrian high of northern Wisconsin toward the axis of the Lake Superior syncline of Minnesota. The general regional dip is about 15 feet per mile in a southwest direction.

16 As this paper goes to press, a paper by Thiel appears (Sedimentary and petrographic analysis of the St. Peter sandstone, Bull. Geol. Soc. Am. 46: 559-614. 1935).

17 Peterson, Eunice. Block faulting in the Saint Croix Valley. Jour. Geol. 35: 368-374. 1927.

Local structure was first noted by one of Owen's [18] party who sketched a large fault on the Saint Croix south of Afton, and another on the Mississippi near Hastings. In 1888, Winchell [19] redescribed the Hastings fault, but interpreted the Afton structure as an anticline, stating: "There is a sudden upward swell in the limestone [Prairie du Chien], both in its lower and its upper surface, running from this point [meaning Hastings], toward the central part of Afton and hence to Hudson. This anticlinal axis can be traced through the central part of Dakota County into the township of Waterford, where it becomes lost in the drift." In the same report, Winchell [20] noticed that the heavy dolomite beds on the Hastings side of Mississippi River show displacement in relation to the beds on the opposite side, but could not locate the fault zone.

In 1915, Weidman and Schultz [21] attributed the structure between Hudson and Burkhart to faulting. In 1919, Peterson [22] mapped and described block faulting near the "Soo" Draw Bridge (8, fig. 1). In 1931, Trowbridge and Atwater [23] thought there must be a fault with a throw of 300 to 400 feet between Stillwater and Hudson, but they had not studied at that time the structure further than this. In 1931, Thwaites [24] quoting Karges [25] described two faults with a horst between them in the lower Saint Croix area. Powers,[26] in 1932, after detailed mapping in the Willow River valley concluded that the structure is anticlinal, and that the evidence of faulting is lacking.

After completion of the field work on which the present paper is based, Trowbridge [27] mapped this structure as an anticline, called it the Hudson anticline, and named the syncline east of it the River Falls syncline and the syncline west of it the Twin City syncline.

18 Owen, D. D. Report of a Geological Survey of Wisconsin, Iowa, and Minnesota. Map Section 1 S. 1852.

19 Winchell, N. H. Geology of Washington County. Geol. of Minn. 2: 382-383. 1888.

20 *Op. cit.*: 382.

21 Weidman, Samuel and A. R. Schultz. Water supplies of Wisconsin. Wis. Geol. and Nat. Hist. Survey 35: 546. 1915.

22 *Op. cit.*

23 Trowbridge, A. C. and G. I. Atwater. Stratigraphy and structure of the Upper Mississippi valley. (Abstract) Geol. Soc. Am. 42: 220. 1931.

24 Thwaites, F. T. Buried Pre-Cambrian of Wisconsin. Geol. Soc. Am. 42: 734-739. 1931.

25 Karges, B. E. Faulting in the Paleozoic sediments near Hudson, Wisconsin. Unpublished thesis, Univ. of Wisconsin. 1930.

26 *Op. cit.*

27 Trowbridge, A. C. Upper Mississippi Valley structure. Bull. Geol. Soc. Am. 45: 519-528. 1934.

After detailed mapping of the region, using the base of the Prairie du Chien as a datum, the writer concludes that the dominating local structure is an anticline with a N. 25½° E. axis passing through Hudson and Afton (structure map, fig. 1), and pitching sharply to the southwest. The northern end of this anticline is covered by drift, but the structure was mapped for nearly twenty miles on the east side of the Mississippi River. On the crest, the datum is fully 500 feet above the normal levels. Because of thick deposits of glacial drift the anticline cannot be traced far to the northeast, but a closure of 100 feet is indicated northeast of Hudson fig. 1). The width of the anticline at Hudson and Afton is between five and six miles. The maximum dip to the east near the Little Falls Dam on the Willow River is 400 feet per mile or more than 4°, and the greatest dips in the south part of the area near Afton and along Trout Creek are somewhat less than that.

The fault at Hastings which trends S. 68° W. intersects the anticlinal structure at a high angle. The total displacement of this almost vertical normal fault could not be definitely determined on account of secondary dolomitization of the Prairie du Chien, but measurable beds show throw of more than 100 feet. As Winchell[28] stated, the Prairie du Chien on the Hastings side of the river is much lower than it is on the Point Douglas side; a fact which indicates that there is a fault in the valley between these two points. Glacial drift and river alluvium make it impossible to locate the fault, and the outcrops to the north and east of this location throw no light on the problem.

On the southeast flank of this anticline, the strata dip to the southeast and south, into the River Falls syncline, at the rate of 100 to 400 feet per mile. North of the anticline, the area has the normal regional dip of approximately 50 feet per mile, and the strike of the strata is almost parallel to Saint Croix River. The only interruption of this normal dip is near the "Soo" Draw Bridge which has been described by Peterson.[29]

CONCLUSIONS

Study of the Saint Croix area throws little if any light on the age of the outcrops of the Keweenawan traps or of the rocks of the Red Clastic Series. Neither has this investigation revealed much concerning their relationship to each other, except that the Red

28 *Op. cit.*: 382.
29 Peterson, Eunice. *Op. cit.*: 368-374.

Clastics are younger than the Keweenawan trap in this particular region.

The Saint Croixan Series can best be divided into three formations: Dresbach, Franconia and Trempealeau. Each of these can be recognized in the field, and their contacts are sharp enough to serve as datum planes in field mapping.

The members of the Dresbach in the Saint Croix area are as easily recognized in the field as is the formation itself, and in a given section, they can be separated in most actions by mechanical analyses and petrographic studies.

The Franconia, like the Dresbach, is divided into members, but the upper two do not have similar lithologic characteristics over an area large enough to warrant naming. In spite of this great variation, the members are distinguishable in the field in the sections in which they occur, and in the laboratory by the high per cent of authigenic feldspars and glauconite.

The members of the Trempealeau can be recognized in most of the Saint Croix area, but in some places the Saint Lawrence and Lodi are indistinguishable.

The writer failed to find evidence for a physical break 60 feet above the Jordan sandstone in the Stillwater section by means either of field or laboratory studies.

The Saint Peter and the Platteville formations are easily recognizable either in the field or in the laboratory.

The dominant structure in the Saint Croix area is the Hudson anticline, which has been thought recently to be a horst.

Mechanical analyses of the samples and a study of both the light and heavy minerals show that the different formations can be differentiated in a given section. It was found that authigenic feldspars and glauconite are very useful in distinguishing the various members; but the writer does not assert that the mineral assemblage found in the Saint Croix section can be used to recognize the different formations and members in sections occurring outside of this area.